A

PROJECT REPORT

ON

“Grid Interconnected Power System Controlled by using Internet”

Submitted in partial fulfillment of the award of

DIPLOMA

IN

ELECTRICAL ENGINEERING

Submitted By

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SESSION 2019-2020

Department of Electrical Engineering

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INTEGRAL UNIVERSITY, LUCKNOW

CERTIFICATE

This is to certify that this team which is comprised of five students of final year **DIPLOMA IN ELECTRICAL ENGINEERING** in this University Centre is presenting a project on **"Grid Interconnected Power System Controlled by using Internet"** as our final year project during the session 2019-2020.

This project is completed for the award **of DIPLOMA IN ELECTRICAL ENGINEERING** from Integral University Centre, Shahjahanpur.

(Project Supervisor/HoD)
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ACKNOWLEDGEMENT

We would like to express my sincere thanks to my project Guide **Er. Mohammad Yasir (Lecturer),** Department of Electrical Engineering, University Polytechnic Shahjahanpur Centre, for his constant support, timely help, guidance, sincere co-operation during the entire period of my work. We are also grateful to him for providing all the necessary facilities during the course of the project work.

We would also like to pay our special thanks to our project supervisor **Er. Mohd. Faraz Khan (HoD),** Department of Electrical Engineering, University Polytechnic Campus, Shahjahanpur for his outstanding help provided during various stages of the project.

Our special thanks goes to In-charge of our Polytechnic **Dr. Mohd. Naseem.** At last but not the least we are want to present our gratitude to **Er. Farazuddin Siddiqui** & **Er. S.A. Rafey** for their full support from time to time in making this project. Apart from this **Mr. Irfan Khan (Lab Instructor)** are also indebted to my heartily thanks for his constant instruction during the whole session in project Lab.

We are also thankful to my loving parents and my colleagues for their moral support & timely help.

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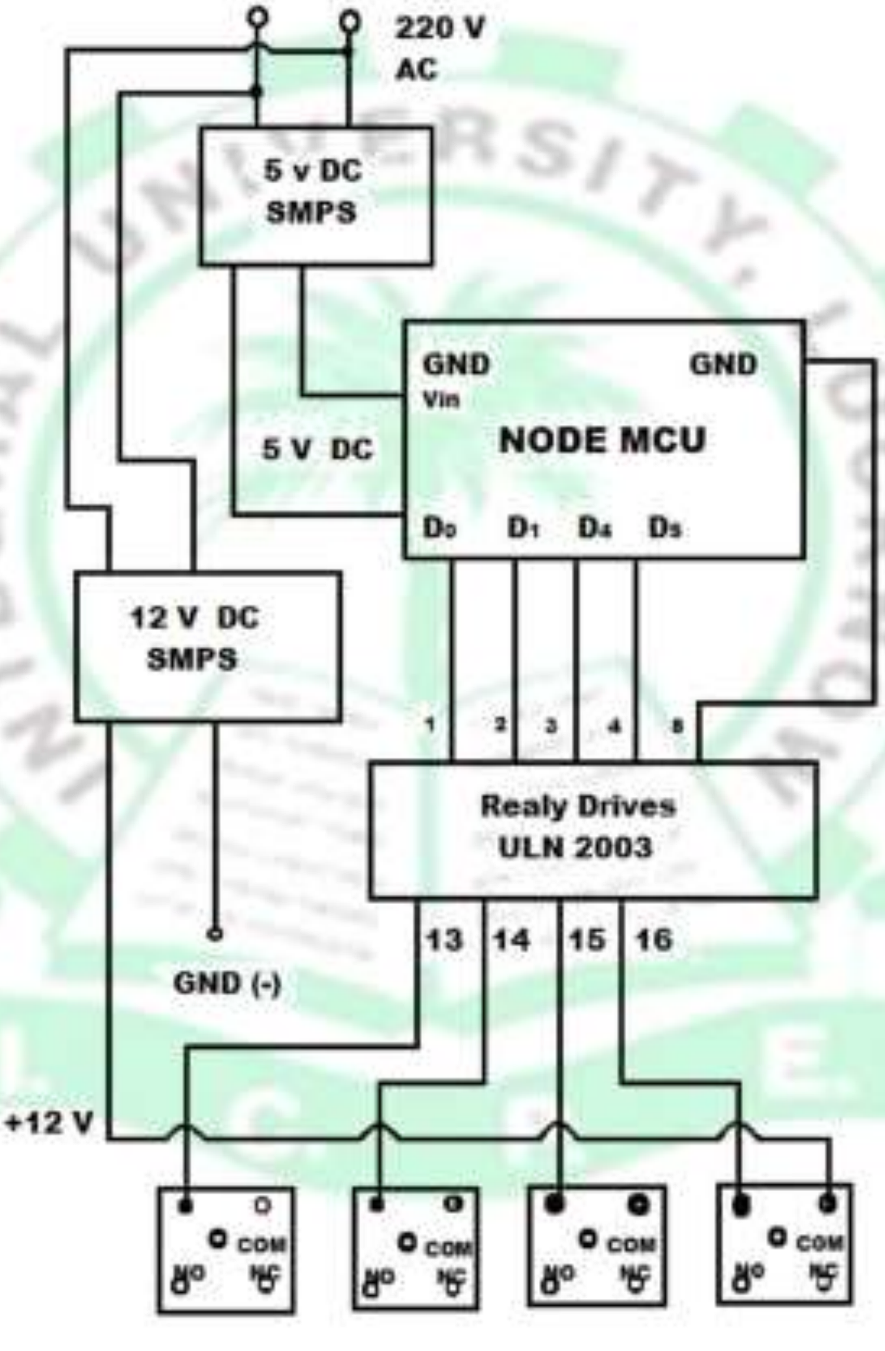
ABSTRACT

Electricity grid interconnections have played a key role in the history of electric power systems. Most International, national and regional power systems that exist today began many decades ago as isolated systems, often as a single generator in a large city. As power systems expanded out from their urban cores, interconnections among neighboring systems became increasingly common. Groups of utilities began to form power pools, allowing them to trade electricity and share capacity reserves. The **interconnected power system** is often referred to as the largest and most complex machine ever built by humankind. The design steps for a Controlled grid connected Power System using a IoT follows the different network topologies. As the Grids arrays are directly connected to the other Grid or Consumer Load.

This Project represents a modern IoT controlling method of Grid interconnected Power System which is designed. Now a days, the power continuity issues are continuously increasing day by day. So, a modern & efficient method is required for on/off of power supply in a particular channel or a grid of an entire interconnected power system. In this working model, the design & switching topology of particular grid of the aforesaid system is controlled by using relay & IoT take place. Because of this topology fast switching can be takes place from any network are in the world through mobile by using Blynk App. The Conventional switching of a Grid requires physical presence at the Control room of particular grid area. Due to voltage sag and voltage swell as well as more maintenance required in conventional system but this problem is removed in this switching technology.

CIRCUIT DIAGRAM OF THE PROJECT



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COMPONENT LIST

S.N.	NAME OF MATERIALS	SPECIFICATION	QUANTITY
1	MICROCONTROLLER	ATMEGA328	1
2	RELAY	12V-8A	4
3	TRANSFORMER	12-0-12	1
4	CAPACITER	470250E	1
		100FU, 25F	2
		PAPER, 104uF	2
5	ADAPTOR	240VAC/7.5VDC, 2.8/60Hz	1
6	WIFI 12E	NODE MCU, ESP8266MOD	1
7	LED	-	4
8	RESISTOR	R2, 10k ohm	2
9	SLIDER SWITCH	CH3406, 9600BPS	1
10	TRANSISTER	SMD2N222	1
11	CRYSTAL OSCILLATOR	16MHz	1
12	DIODE	IN4007	1
13	VOLTAGE REGULATOR	LM7805	1
14	Power Supply	**220V**	1
15	RECTIFIER	STD	2
16	Multimeter	STD	1
17	SMPS ADAPTOR	5V, 2A	1
18	INTEGRATED CIRCUIT	IC ESP8266	1
19	SOCKET POINT (CONNECTOR)	5A/15A	1
22	SOLDERING IRON	MINIPWRK/TMRK	5
25	GLUE GUN	J2, SMALL	1
26	SOLDERING PASTE	SMALL	1
27	SOLDERING WIRE	SMALL	1

OVERVIEW

Title of the Project:

Grid Interconnected Power System Controlled by Using Internet

Domain:

Control System
Switchgear & Protection
Power System

Software:

Arduino 1.8.5
BlynK App

Microcontroller& IC:

ATMEGA328
ESP8266MOD, ESP8266ND

Power Supply:

230 V AC
12 V DC

Display:

N/A

Transformer:

230 V / 12 V AC

Voltage Regulator:

LM 7805

Communication Device:

N/A

Applications:

For Automated Interconnected Power System.
For Self-operated Power Grid
For Power System Networks

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BASE PAPER

Chapter 1: ABOUT PROJECT 1-2

1.1 INTRODUCTION 1
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CHAPTER-1: ABOUT PROJECT

In this chapter the basic introduction about the idea of project including objective & thesis organization is given in short.

1.1 INTRODUCTION

This Project represents an advanced model of Control for a grid interconnected power system. In this project the all connected channels are controlled by using IoT technology. Through this means of control we can turn on/off any relevant supply connected to it. Today in this modern era the power control issues are continuously increasing day by day. Then new controlling method is required for this. So, we designed a power switching topology for grids by using relay & IoT take place. Because of this topology fast switching can be takes place effectively. In mechanical switching arc maybe produced due to fault and also may require more time than other technologies due to voltage sag and voltage swell as well as more maintenance required. This problem is removed in this switching idea. It has been tested for reliability and for maintaining the operation under the respective parameters such as cut off voltage/current of the power system. The microcontroller generated signal and pass the signal to relay driver circuit.

Power control issue is increasing day by day. Then there is requirement of new technology of automatic cut off for power supply. So conventionally, the relays are used as switching topology. The main factor in power utilization is the customer demanded an uninterrupted supply is minimum disturbance and also in power utilities it reduces. By considering above, we focuses on the switching of power grid from anywhere in the world. In old topologies mechanical/conventional switching topologies were used for this purpose. There is number of modern technologies but this work presents relay topology or power switching of any connected branch of a grid.

1.2 AIM OF THE PROJECT

The main aim of this project is save man power to achieve modern control of power grids from anywhere in the world in Grid interconnected power system. This is mainly done by the controlling the relays thorough Internet. By analyzing the Arduino program, our system control these relays on finger tips no matter is of distance.

In earlier years we use manually switching in electrical system to supply power through isolator. These isolators having some problems like as, electric shock, produces arching at each time of power cut off requirement, extra man power & require regular maintenance also few problem are occurs such as over voltage, under voltage, voltage sag, voltage swell etc. so due to this problem power supplier do not provide uninterrupted power supply to the consumer. To provide the uninterrupted power supply one of the methods is by employing microcontroller based on-load tap changer for small a grid interconnected power system. It has fast response as compare to the manually operated isolator also problem of arcing during on/off is not occurs & due to use of relay as switching device problem of harmonics are also eliminated. So the aim behind this project is to provide uninterrupted power supply to the consumer but there may be a possibility of slow performance (depends upon the connectivity of internet) during the turn on/off.

1.3 THESIS OF ORGANIZATION

The structure of the entire thesis organization is as following:

Chapter -1: the basic introduction about the project including the requirement of power switching in grid interconnected power system and thesis organization is also given in short.

Chapter -2: In this chapter covers the Concept of IoT domain focusing the history, existing setup and future scope of it in India & abroad.

Chapter -3: In this chapter the basic useful components used in this project are described in detail along with the concept of tap changing & working of prototype.

Chapter -4 In this chapter the software modulation, programming, coding etc are described for Arduino 1.8.2, MICROCONTROLLOR & BLYNK APP through sketching out its programs & blocks.

Chapter -5: This chapter is the valedictory of our project thesis in which we wrote the final conclusion of our Project illustrating the result along-with the short discussion about the future scope of our presented model.

We also included a separate section for Reference & Appendix in this Thesis.

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CHAPTER 2: ABOUT IOT TECHNOLOGY

In this chapter we describe the Concept of IoT domain focusing the history, existing setup and future scope of it in India & abroad.

2.1 INTRODUCTION:

The Internet of things (IoT) is the extension of Internet connectivity into physical devices and everyday objects. Embedded with electronics, Internet connectivity, and other forms of hardware (such as sensors), these devices can communicate and interact with others over the Internet, and they can be remotely monitored and controlled. The definition of the Internet of things has evolved due to convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers. The IoT concept has faced prominent criticism, especially in regards to privacy and security concerns related to these devices and their intention of pervasive presence.

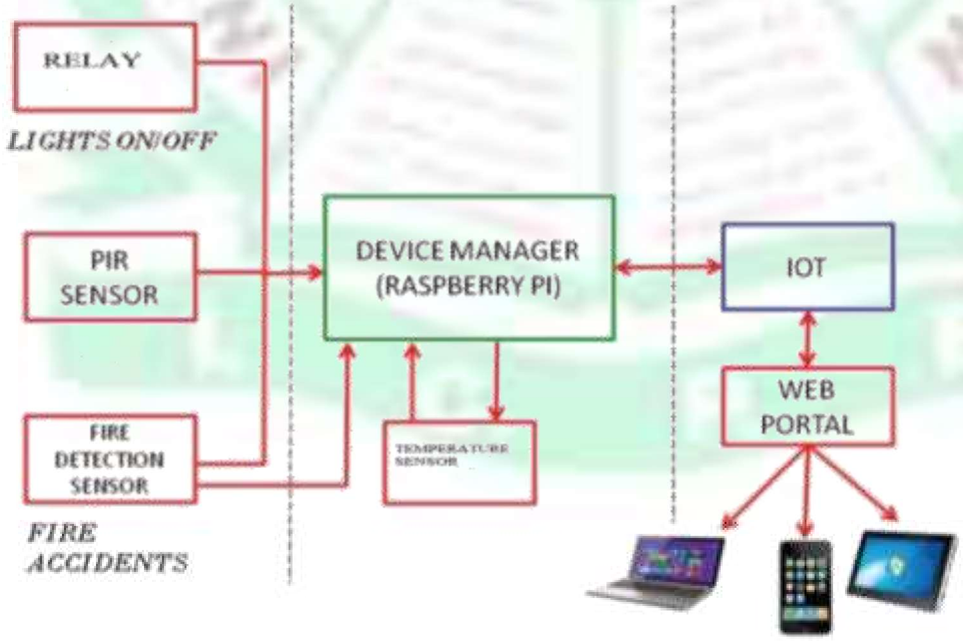
In IoT technology the system is designed to control it through Internet. So no matter what is the distance between its operator & the real working hardware. Now a days Internet of Thing is the phenomenon which is modified towards the internet of everything.

The extensive set of applications for IoT devices is often divided into consumer, commercial, industrial, and infrastructure spaces. For Example: Automation, Robotics, Domestic home appliance control, Electrical machine control etc.

2.2 HISTORY OF IoT:

The concept of a network of smart devices was discussed as early as 1982, with a modified Coke vending machine at Carnegie Mellon University becoming the first Internet-connected appliance, able to report its inventory and whether newly loaded drinks were cold or not.[7] Mark Weiser's 1991 paper on ubiquitous computing, "The Computer of the 21st Century", as well as academic venues such as UbiComp and PerCom produced the contemporary vision of the IoT. In 1994, Reza Raji described the concept in IEEE Spectrum as "[moving] small packets of data to a large set of nodes, so as to integrate and automate everything from home appliances to entire factories". Between 1993 and 1997, several companies proposed solutions like Microsoft's at Work or Novell's NEST. The field gained momentum when Bill Joy envisioned device-to-device communication as a part of his "Six Webs" framework, presented at the World Economic Forum at Davos in 1999. The term "Internet of things" was likely coined by Kevin Ashton of Procter & Gamble, later MIT's Auto-ID Center, in 1999, though he prefers the phrase "Internet for things". At that point, he viewed Radio-frequency identification (RFID) as essential to the Internet of things,[14] which would allow computers to manage all individual things. A research article mentioning the Internet of Things was submitted to the conference for Nordic Researchers in Norway, in June 2002, which was preceded by an article published in Finnish in January 2002. The implementation described there was developed by Kary Främling and his team at Helsinki University of Technology and more closely matches the modern one, i.e. an information system infrastructure for implementing smart, connected objects.Defining the Internet of things as "simply the point in time when more 'things or objects' were connected to the Internet than people", Cisco Systems estimated that the IoT was "born" between 2008 and 2009, with the things/people ratio growing from 0.08 in 2003 to 1.84 in 2010.

2.3 BLOCK DIAGRAM OF IoT:-



2.4 FUTURE OF IOT:

It’s the technology of today which is touching and transforming the every aspect of our real life. IOT has given a concept of Machine to-Machine (M2M) communication. Companies like Microsoft and SAP are implementing strategy to capitalize on the Internet of Things so that you can just stop your business and start making it thrive. IOT is going to have huge impact on home automation and building automation system where every convenience will be taken care of by the interconnected devices on IOT. It is also deployed on large scale for example in Songdo , South Africa , the first of its own kind fully equipped and wired smart city is near to completion (known as Ubiquitous City). With the personal electronics good connected to Internet will enable us to “author” our lives. In medical science field, IOT has given a privilege to devices and system to sense for coming disease and to prevent it ,for eg: It can make a person healthier with wearables that can predict heart attack and cardiovascular strokes. As per a report of The suns daily, consumers will start initiating the usage of IoT in a better way during 2015 and onwards compared to past usage. It is expected that IoT products with interoperable capability will dominate the market. Awareness of IoT products is also vital for market penetration along with security features. Even very few Americans are aware of the usage of these products. As per a study of Consumer Electronics Association and Parks Associates found only 10% of the household in USA fully understood the usage of these products. Many interesting IoT products like automatic door locks, Wi-Fi connected ceiling fans, light swirches, LED bulbs, smart watches,3-D printers and smart clothes will be popular among consumers. My Brain Technology in France has developed "Melomind". This EEG Headset can measure a human's brain waves and adjust music in a Smartphone app as they change. This product can be used as a digital meditation aid. A smart baby pacifier can measure the temperature of a baby and transmit the same to the Smartphone of parents. IoT is proved to be an emerging technological innovation. In the current context, it is now possible that an helmet of a two wheeler can interact with a car for avoiding collision. Connected toothbrush can now monitor and make one's experience pleasurable .A three dimensional senor of the electric brush can connect with Smartphone apps and provide real time feedback to the person. Many scopes will be created for technology companies to release offerings as per the behavior of consumers. It may so happen that Netflix can know when a person is sad and alone by monitoring the smart watch, smart thermostat and in-home camera. Subsequently, Netflix may offer a movie to change the mood. In a consumer electronics show in Los Vegas, Samsung informed that the company would invest 100 million dollar for progress of IoT. The company will also promote an open technology ecosystem for facilitating the usage of IoT.

2.5 FUTURE OF IOT IN INDIA:

There is a lot of scope for IoT in future. The world will have approximately 40 billion connected devices by 2020. IoT is foreseen to touch every industry and people in every domain, optimizing businesses and simplifying people's lives.

In India IoT mainly focuses on following things:

- Industrial IoT
- Connected Cars
- Smart Security
- Big Data
- Smart Cities
- Data Analysis
- Smart Healthcare
- Smart Parking
- Energy Management
- Fleet Management
- Home Automation
- Smart Businesses
- Smart Environment Monitoring
- Smart Banking

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Chapter 3: HARDWARE DESIGN AND WORKING 7-14

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CHAPTER-3- HARDWARE DESIGN AND WORKING

In this chapter the basic useful components used in this project are described in detail along with the concept of tap changing & working of prototype.

3.1 Power Grid

An electrical grid, electric grid or power grid, is an interconnected network for delivering electricity from producers to consumers. Or on other words we can say that. The electrical grid is the electrical power system network comprised of the generating plant, the transmission lines, the substation, transformers, the distribution lines and the consumer.

It supplies the electrical power from generating unit to the distribution unit. A large amount of power is transmitted from the generating station to load center at 220kV or higher. The network form by these high voltage lines is called the super grid. The super grid feeds the sub-transmission network operating at 132kV or less

A smart grid can help utilities conserve energy, reduce costs, increase reliability and transparency, and make processes more efficient. The increasing use of IT-based electric power systems, however, increases cyber security vulnerabilities, which increases cyber security's importance. Through this interconnected network the delivering electric power supply from producers to consumers become more easy, balance, efficient & effective. It also enables taking advantage of diversity of loads, availability of sources, and fuel price in order to supply electricity to the loads at minimum cost with a required reliability. Through this all plants are connected so, the reserve capacity of the system is reduced and it increase the efficiency of the system. Also it reduces capital and operating cost.

The interconnection of the grid provides the best use of power resource and ensures great security to supply. It makes the system economical and reliable. The generating stations are interconnected for reducing the reserve generation capacity in each area.

If there is a sudden increase in load or loss of generation in a zone, then it borrows from the adjacent interconnected area. But for the interconnections of the network certain amount of generating capacity known as the spinning reserve is required. The spinning reserve consists generator running at normal speed and ready to supply power instantaneously.

3.2 Classification of Power Grid

The power station of the grid is located near the fuel source which reduces the transportation cost of the system. But it is located far away from the populated areas. The power which is generated at high voltage is stepped down by the help of step down transformer in the substation and then supply to the consumers. The electrical grid is mainly classified into two types. They are:

a) **Regional Grid –** The Regional grid is formed by interconnecting the different transmission system of a particular area through the transmission line.

b) National Grid – It is formed by interconnecting the different regional grid.

3.3 Power Grid Interconnection Topologies:

The interconnection of power system networks is mainly classified into two types, i.e., the HVAC link and HVDC link.

a) HVAC (High Voltage Alternating Current) Interconnection. ...

b) HVDC (High Voltage Direct Current) Interconnection

But according to the connection the following topologies are adopted:

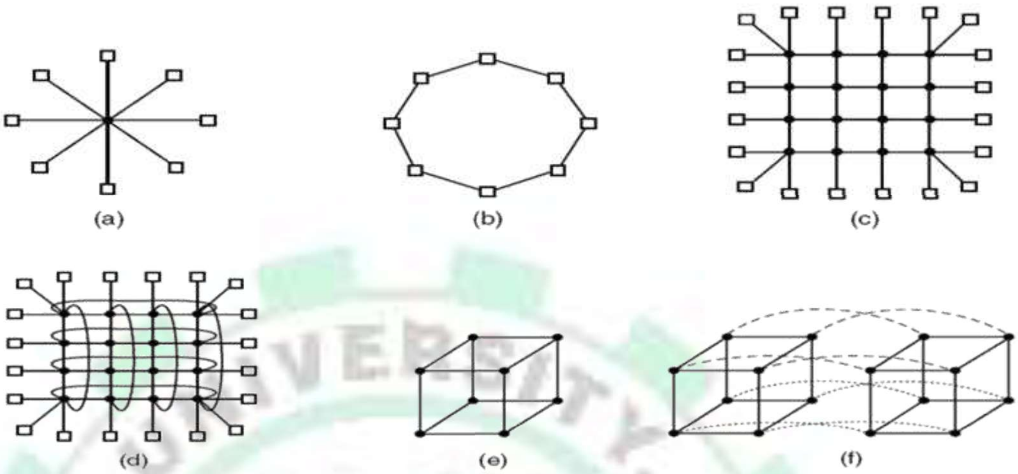
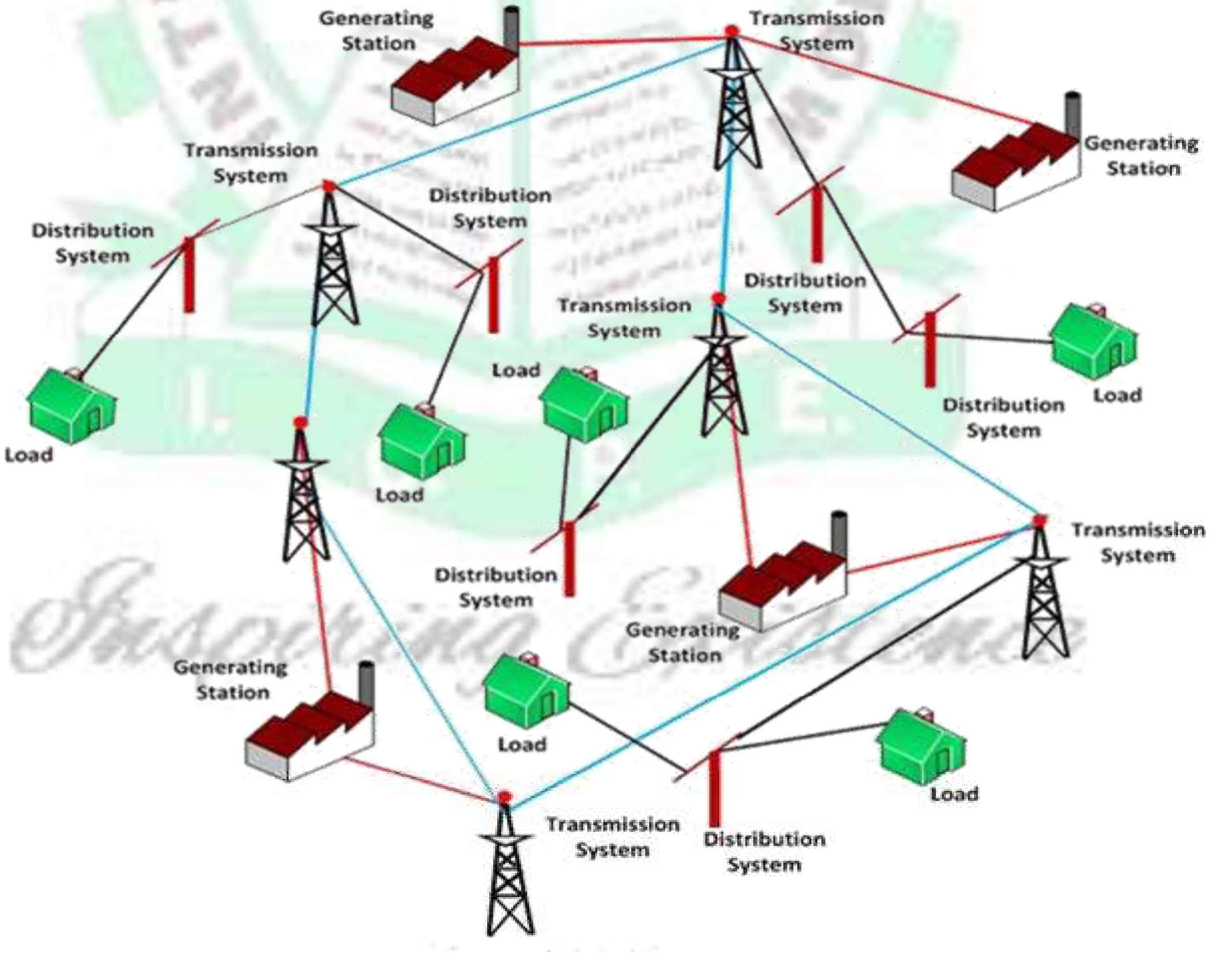


Figure 8-16. Various interconnect topologies.
(a) A single switch (b) A ring (c) A grid or mesh (d) A double torus
(e) A cube (f) A 4D hypercube

Basically a, b & c are the three main topologies but among all of these a is widely used and the most common topology for this purpose. The typical layout of a single switched topology is used to install a common electric grid.



3.4 RELAY & RELAY DRIVER CIRCUIT

a) RELAY

A relay is an electrically operated switch. Current flowing through the coil of the relay creates a magnetic field, which attracts a lever and changes the switch contacts. The coil current can be on or off so relays have two switch positions and they are double throw (changeover) switches. Relays allow one circuit to switch a second circuit that can be completely separate from the first. For example a low voltage battery circuit can use a relay to switch a 230V AC mains circuit. There is no electrical connection inside the relay between the two circuits, the link is magnetic and mechanical.

The coil of a relay passes a relatively large current, typically 30mA for a 12V relay, but it can be as much as 100mA for relays designed to operate from lower voltages. Most ICs (chips) cannot provide this current and a transistor is usually used to amplify the small IC current to the larger value required for the relay coil. The maximum output current for the popular 555 timer IC is 200mA so these devices can supply relay coils directly without amplification.

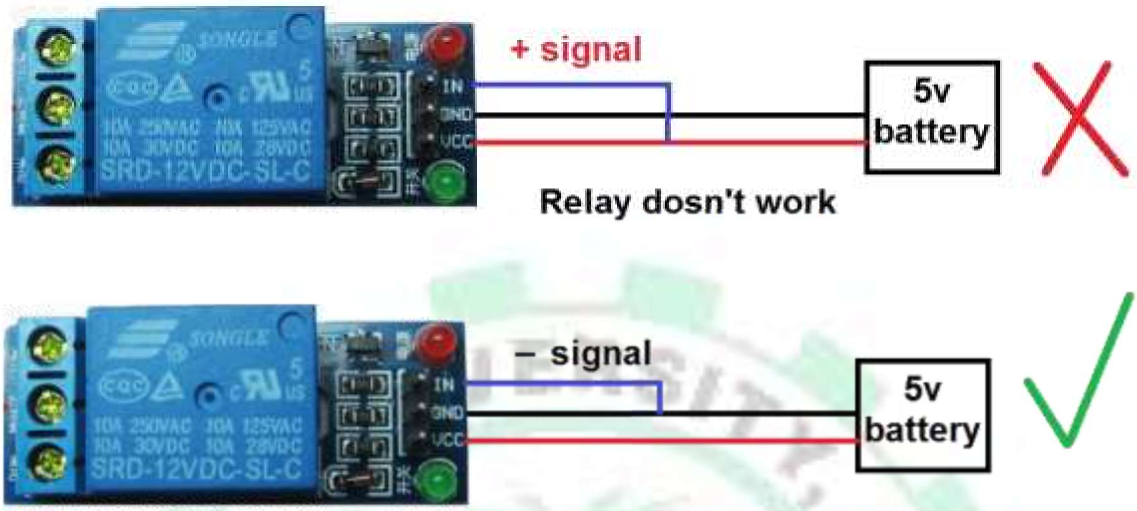
Relays are usually SPDT or DPDT but they can have many more sets of switch contacts, for example relays with 4 sets of changeover contacts are readily available. For further information about switch contacts and the terms used to describe them please see the page on switches.

Most relays are designed for PCB mounting but you can solder wires directly to the pins providing you take care to avoid melting the plastic case of the relay.

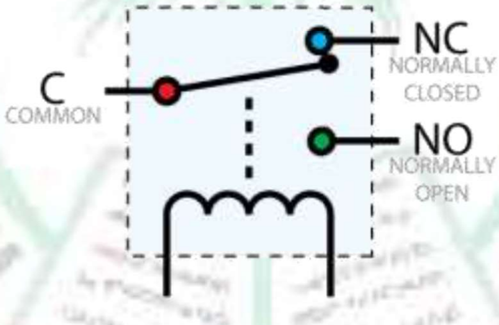
The supplier's catalogue should show you the relay's connections. The coil will be obvious and it may be connected either way round. Relay coils produce brief high voltage 'spikes' when they are switched off and this can destroy transistors and ICs in the circuit. To prevent damage you must connect a protection diode across the relay coil.

The animated picture shows a working relay with its coil and switch contacts. You can see a lever on the left being attracted by magnetism when the coil is switched on. This lever moves the switch contacts. There is one set of contacts (SPDT) in the foreground and another behind them, making the relay DPDT.

Inspiring Existence



RELAY WIRE CONNECTION



RELAY

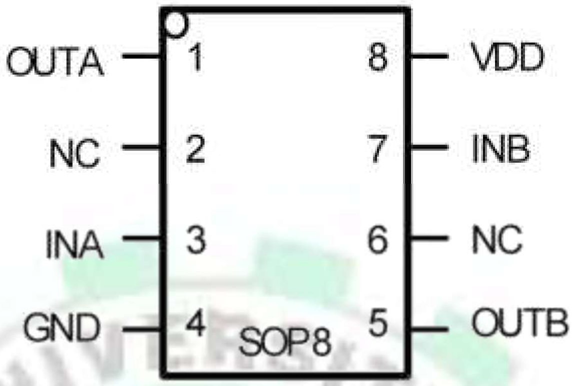
The relay's switch connections are usually labeled COM, NC and NO:

- COM = Common, always connect to this, it is the moving part of the switch.
- NC = Normally Closed, COM is connected to this when the relay coil is off.
- NO = Normally Open, COM is connected to this when the relay coil is on.
- Connect to COM and NO if you want the switched circuit to be on when the relay coil is on.
- Connect to COM and NC if you want the switched circuit to be on when the relay coil is off.

b) RELAY DRIVER CIRCUIT

A relay driver circuit is a circuit which can drive, or operate, a relay so that it can function appropriately in a circuit. The driven relay can then operate as a switch in the circuit which can open or close, according to the needs of the circuit and its operation. In this project, we will build a relay driver for both DC and AC relays. Since DC and AC voltages operate differently, to build relay drivers for them requires slightly different setup. We will also go over a generic relay driver which can operate from either AC or DC voltage and operate both AC and DC relays. All the circuits are relatively simple to understand.

A Relay driver Circuit is actually an IC which is an electro-magnetic switch that will be used whenever we want to use a low voltage circuit to switch a light bulb ON and OFF which is connected to 220V mains supply. There are various ways to drive relays. A Relay Driver ICs used in our project is given here in the figure below:



Relay Driver IC

The required current to run the relay coil is more than can be supplied by various integrated circuits like Op-Amp, etc. Relays have unique properties and are replaced with solid state switches that are strong than solid-state devices. High current capacities, capability to stand ESD and drive circuit isolation are the unique properties of Relays. There are various ways to drive relays. Some of the Relay Driver ICs are as below:

- High side toggle switch driver
- Low side toggle switch driver
- Bipolar NPN transistor driver
- N-Channel MOSFET driver and
- Darlington transistor driver
- ULN2003 driver

Relay driver circuit used for the switching an interconnected grid of an interconnected power system. Signal is passes from microcontroller to relay and the relay is operated. In relay driver circuit seven relays are used. For one tap one relay is used. Specifications of relays are as follows:

S.N.	Parameters	Value
1	Voltage	250V AC/ 12V DC
2	Current Capacity	10 A
3	On/off Switching Capacity	30 operation/min
4	Operating Time	10 m sec

Inspiring Existence

3.5 POWER SUPPLY & RECTIFIER

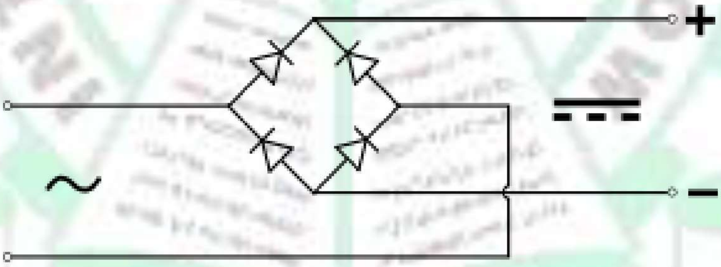
A) POWER SUPPLY

Generally a power supply is always used to run any electrical or Electronic device. I this project Main power supply of 230V AC is used through which AC Load can be operated after tap changing in output side of given cut section of transformer.

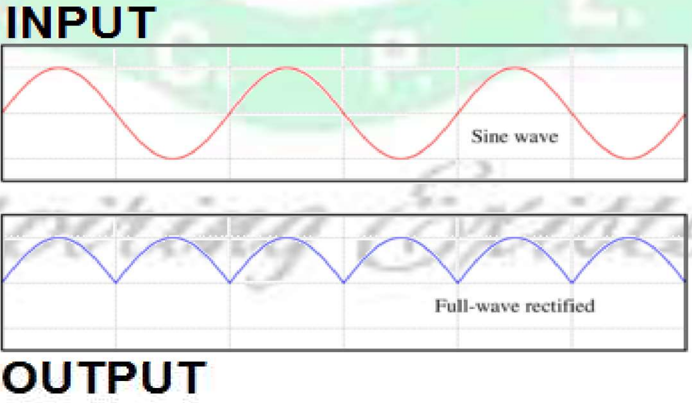
But for controlling this tap an Electronic circuit is used in which node MCU is connected with relays and other necessary things we require a regulated DC power supply. This DC Power can be achieved by using Bridge Rectifier circuit. For this by using step down transformer 230V is converted to 12V AC. Further it is converted to 5V DC by using Bridge rectifier, capacitor and LM7805 voltage regulator

B) RECTIFIER

A bridge rectifier is an arrangement of four diodes connected in a bridge circuit as shown below, that provides the same polarity of output voltage for any polarity of the input voltage. When used in its most common application, for conversion of alternating current (AC) input into direct current (DC) output, it is known as a bridge rectifier. The bridge rectifier provides full wave rectification from a two wire AC input (saving the cost of a center tapped transformer) but has two diode drops rather than one reducing efficiency over a center tap based design for the same output voltage.

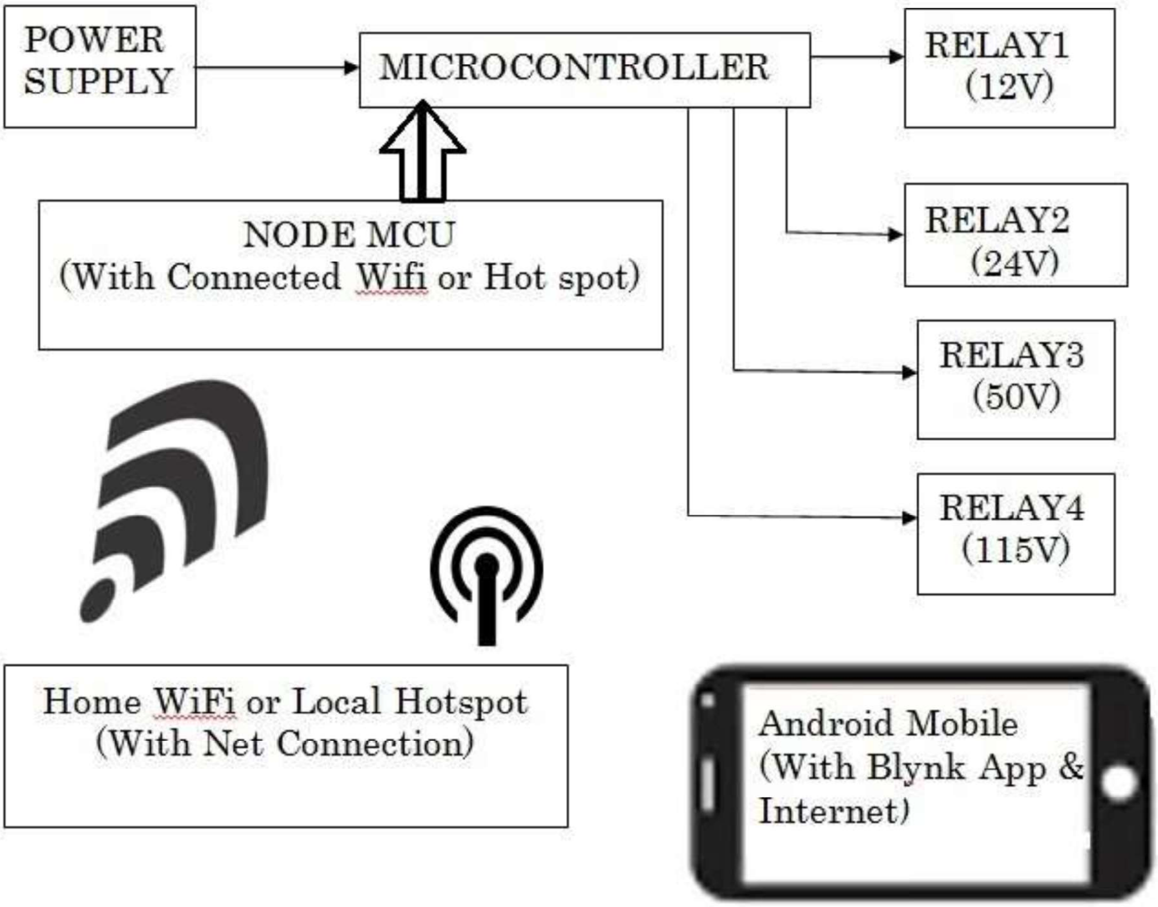


The essential feature of this arrangement is that for both polarities of the voltage at the bridge input, the polarity of the output is constant.



3.6 WORKING MODEL

The block diagram of IoT Controlled Grid unit of any given grid interconnected power system is shown in figure below:


POWER SUPPLY
MICROCONTROLLER
RELAY1 (12V)
RELAY2 (24V)
RELAY3 (50V)
RELAY4 (115V)
NODE MCU (With Connected Wifi or Hot spot)
Home WiFi or Local Hotspot (With Net Connection)
Android Mobile (With Blynk App & Internet)

There are various components in in this project which are Relay driver, Node MCU circuit, Microcontroller unit etc. In the block diagram tap changing transformer is connected to relay driver circuit unit Containing microcontroller and relays are connected to load. The relay driver circuit is control by the microcontroller unit to change the tap on the output side of given cut section transformer. Microcontroller, is named as ATMEGA328, is used because of fast processing of tap changing transformer. Also CT sensor may be used to sense the voltage and current of load then pass the signal to microcontroller unit. In microcontroller unit program is fed & in NODE MCU an Arduino program is fed as per the authentication token generated online through BLYNK App. Then an Arduino mobile is used to operate the tap changing by using Android App BLYNK. Suppose this mobile is in my pocket at London. An online setup of Microcontroller, NODE MCU, Relay driver, Cut section of Auto Transformer etc is here in India. When a command on android Smartphone is given from London through BLYNK APP then online system sense it and generates Microcontroller signal and pass the signal to relay driver circuit. Then relay driver circuit is operated and particular relay of taps of respective grid unit. Because at a time only a single relay operates hence a single voltage is obtained through a particular output terminal at given voltage terminal among these four terminals.

RESULT

I/p Grid	o/p Grid	Relay1 Tap 1	Relay2 Tap 2	Relay3 Tap 3	Relay4 Tap 4
Grid 1	Grid 2	ON	off	off	off
Grid 1	Grid 3	off	ON	off	off
Grid 1	Grid 4	off	off	ON	off
Grid 1	Grid 5	ON	ON	ON	ON
Grid 1	Grid 2	ON	off	off	off
Grid 1	Grid 3	off	ON	ON	off
Grid 1	Grid 4	off	off	ON	ON
Grid 1	Grid 5	off	ON	ON	ON
Grid 1	Grid 2	ON	ON	off	off

Grid 1 is the Mother grid for Grid 2, Grid 3, Grid 4, Grid 5. Similarly any one of these grid (i. e. Grid 2, Grid 3, Grid 4, Grid 5) may be mother grid for Grid 6 and So on……..

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Chapter 4: SOFTWARE MODULATION &ARDUINO UNO **15-24**

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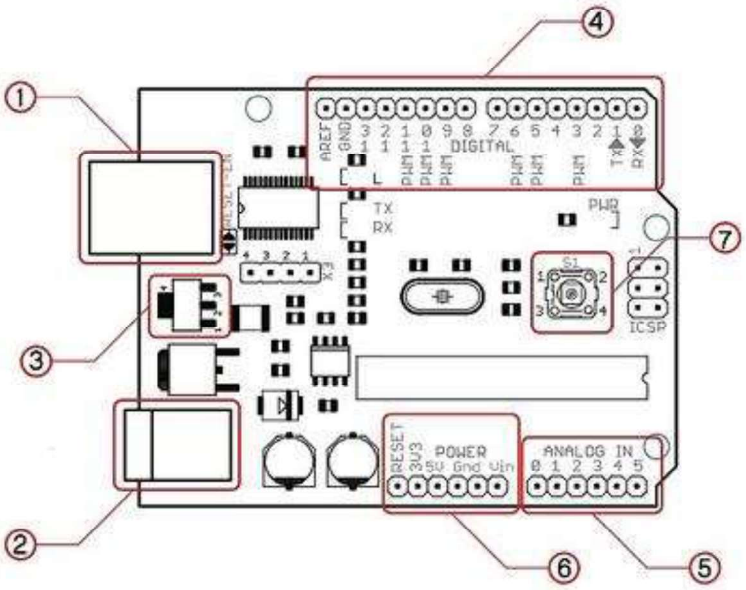
Chapter 4: SOFTWARE MODULATION & ARDUINO UNO

In this chapter the software modulation, programming, coding etc are described for Arduino 1.8.2, MICROCONTROLLOR & BLYNK APP through sketching out its programs & blocks.

4.1 WHAT IS ARDUINO

Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control both physically and digitally. Its products are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.



The most important parts on the Arduino board high lighted in red:

1: USB connector
2: Power connector
3: Automatic power switch
4: Digital pins
5: Analog pins
6: Power pins
7: Reset switch

Arduino board designs use a variety of microprocessors and controllers. The boards are equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards or breadboards (shields) and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, which are also used for loading programs from personal computers. The microcontrollers are typically programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

The Arduino project started in 2003 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, thermostats and motion detectors.

The name Arduino comes from a bar in Ivrea, Italy, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014.

4.2 HISTORY OF ARDUINO

The Arduino project was started at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. At that time, the students used a BASIC Stamp microcontroller at a cost of $50, a considerable expense for many students. In 2003 Hernando Barragán created the development platform Wiring as a Master's thesis project at IDII, under the supervision of Massimo Banzi and Casey Reas. Casey Reas is known for co-creating, with Ben Fry, the Processing development platform. The project goal was to create simple, low cost tools for creating digital projects by non-engineers. The Wiring platform consisted of a printed circuit board (PCB) with an ATmega168 microcontroller, an IDE based on Processing and library functions to easily program the microcontroller. In 2003, Massimo Banzi, with David Mellis, another IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they forked the project and renamed it Arduino.

The initial Arduino core team consisted of Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, and David Mellis, but Barragán was not invited to participate.

Following the completion of the Wiring platform, lighter and less expensive versions were distributed in the open-source community.

It was estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced, and in 2013 that 700,000 official boards were in users' hands.

In October 2016, Federico Musto, Arduino's former CEO, secured a 50% ownership of the company. In April 2017, Wired reported that Musto had "fabricated his academic record.... On his company's website, personal LinkedIn accounts, and even on Italian business documents, Musto was until recently listed as holding a PhD from the Massachusetts Institute of Technology. In some cases, his biography also claimed an MBA from New York University." Wired reported that neither University had any record of Musto's attendance, and Musto later admitted in an interview with Wired that he had never earned those degrees.

The controversy surrounding Musto continued when, in July 2017, he reportedly pulled many Open source licenses, schematics, and code from the Arduino website, prompting scrutiny and outcry.

In October 2017, Arduino announced its partnership with ARM Holdings (ARM). The announcement said, in part, "ARM recognized independence as a core value of Arduino ... without any lock-in with the ARM architecture." Arduino intends to continue to work with all technology vendors and architectures.

In early 2008, the five co-founders of the Arduino project created a company, Arduino LLC, to hold the trademarks associated with Arduino. The manufacture and sale of the boards was to be done by external companies, and Arduino LLC would get a royalty from them. The founding bylaws of Arduino LLC specified that each of the five founders transfer ownership of the Arduino brand to the newly formed company.[citation needed]

At the end of 2008, Gianluca Martino's company, Smart Projects, registered the Arduino trademark in Italy and kept this a secret from the other cofounders for about two years. This was revealed when the Arduino company tried to register the trademark in other areas of the world (they originally registered only in the US), and discovered that it was already registered in Italy. Negotiations with Gianluca and his firm to bring the trademark under control of the original Arduino company failed. In 2014, Smart Projects began refusing to pay royalties. They then appointed a new CEO, Federico Musto, who renamed the company Arduino SRL and created the website arduino.org, copying the graphics and layout of the original arduino.cc. This resulted in a rift in the Arduino development team.

In January 2015, Arduino LLC filed a lawsuit against Arduino SRL.

In May 2015, Arduino LLC created the worldwide trademark Genuino, used as brand name outside the United States.

At the World Maker Faire in New York on October 1, 2016, Arduino LLC co-founder and CEO Massimo Banzi and Arduino SRL CEO Federico Musto announced the merger of the two companies.

By 2017 Arduino AG owned many Arduino trademarks. In July 2017 BCMI, founded by Massimo Banzi, David Cuartielles, David Mellis and Tom Igoe, acquired Arduino AG and all the Arduino trademarks. Fabio Violante is the new CEO replacing Federico Musto, who no longer works for Arduino AG.

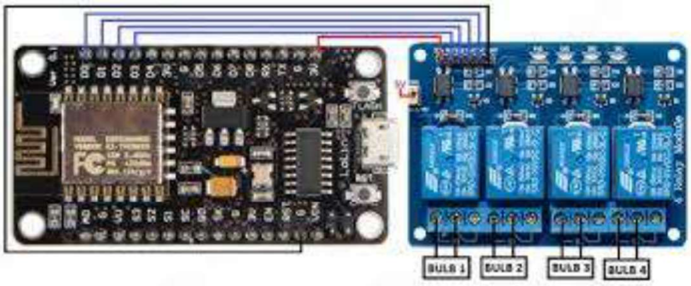
4.3 SOFTWARE

A program for Arduino hardware may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their 8-bit AVR and 32-bit ARM Cortex-M based microcontrollers: AVR Studio (older) and Atmel Studio (newer).

a) IDE

The Arduino integrated development environment (IDE) is a cross-platform application (for Windows, macOS, Linux) that is written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The source code for the IDE is released under the GNU General Public License, version 2.

The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal encoding that is loaded into the Arduino board by a loader program in the board's firmware.



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b) Sketch

A sketch is a program written with the Arduino IDE. Sketches are saved on the development computer as text files with the file extension .ino. Arduino Software (IDE) pre-1.0 saved sketches with the extension .pde.

A minimal Arduino C/C++ program consist of only two functions:

setup(): This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch.
loop(): After setup() function exits (ends), the loop() function is executed repeatedly in the main program. It controls the board until the board is powered off or is reset.

Blink example

Power LED and Integrated LED on Arduino Compatible Board
Power LED (red) and User LED (green) attached to pin 13 on an Arduino compatible board
Most Arduino boards contain a light-emitting diode (LED) and a current limiting resistor connected between pin 13 and ground, which is a convenient feature for many tests and program functions. A typical program used by beginners, akin to Hello, World!, is "blink", which repeatedly blinks the on-board LED integrated into the Arduino board. This program uses the functions pinMode(), digitalWrite(), and delay(), which are provided by the internal libraries included in the IDE environment. This program is usually loaded into a new Arduino board by the manufacturer.

```
#define LED_PIN 13              // Pin number attached to LED.
void setup() {
pinMode(LED_PIN, OUTPUT);       // Configure pin 13 to be a digital output.
}
void loop() {
digitalWrite(LED_PIN, HIGH);    // Turn on the LED.
delay(1000);                    // Wait 1 second (1000 milliseconds).
digitalWrite(LED_PIN, LOW);     // Turn off the LED.
delay(1000);                    // Wait 1 second.
}
```

4.4 ARDUINO CODING

Arduino coding is based on programming language. So After understanding the hardware of the Arduino UNO board in the previous article, let's now get started with Arduino programming.

Arduino programs are written in the Arduino Integrated Development Environment (IDE). Arduino IDE is a special software running on your system that allows you to write sketches (synonym for program in Arduino language) for different Arduino boards. The Arduino programming language is based on a very simple hardware programming language called processing, which is similar to the C language. After the sketch is written in the Arduino IDE, it should be uploaded on the Arduino board for execution.

The first step in programming the Arduino board is downloading and installing the Arduino IDE. The open source Arduino IDE runs on Windows, Mac OS X, and Linux. Download the Arduino software (depending on your OS) from the official website and follow the instructions to install.

Now let's discuss the basics of Arduino programming.

The structure of Arduino program is pretty simple. Arduino programs have a minimum of 2 blocks,

Preparation & Execution

Each block has a set of statements enclosed in curly braces:

```
void setup( )

{

statements-1;

.

.

.

statement-n;

}

void loop ( )

{

statement-1;

.

.

.

statement-n;

}
```

Here, setup ( ) is the preparation block and loop ( ) is an execution block.

The setup function is the first to execute when the program is executed, and this function is called only once. The setup function is used to initialize the pin modes and start serial communication. This function has to be included even if there are no statements to execute.

```
void setup ( )

{

pinMode (pin-number, OUTPUT); // set the ‘pin-number’ as output

pinMode (pin-number, INPUT); // set the ‘pin-number’ as output

}
```

After the setup ( ) function is executed, the execution block runs next. The execution block hosts statements like reading inputs, triggering outputs, checking conditions etc..

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In the above example loop ( ) function is a part of execution block. As the name suggests, the loop( ) function executes the set of statements (enclosed in curly braces) repeatedly.

```
Void loop ( )

{

digitalWrite (pin-number,HIGH); // turns ON the component connected to ‘pin-number’

delay (1000); // wait for 1 sec

digitalWrite (pin-number, LOW); // turns OFF the component connected to ‘pin-number’

delay (1000); //wait for 1sec

}
```

Note: Arduino always measures the time duration in millisecond. Therefore, whenever you mention the delay, keep it in milli seconds.

Now, let’s take a giant leap and do some experiments with Arduino

Blinking the LED
Fade-in and fade-out the LED
In the process of experimenting with Arduino, writing the Arduino program is not the only important thing, building the breadboard circuit is equally important.

Let’s take a look at how the breadboard circuit has to be built for both the experiments.

Components required:

Arduino UNO R3 -1
Breadboard -1
Breadboard connectors -3
LED -1
1K resistor -1
Blinking LED

Steps in building a breadboard connection:

Step-1: Connect the Arduino to the Windows / Mac / Linux system via a USB cable

Step-2: Connect the 13th digital pin of Arduino to the positive power rail of the breadboard and GND to the negative

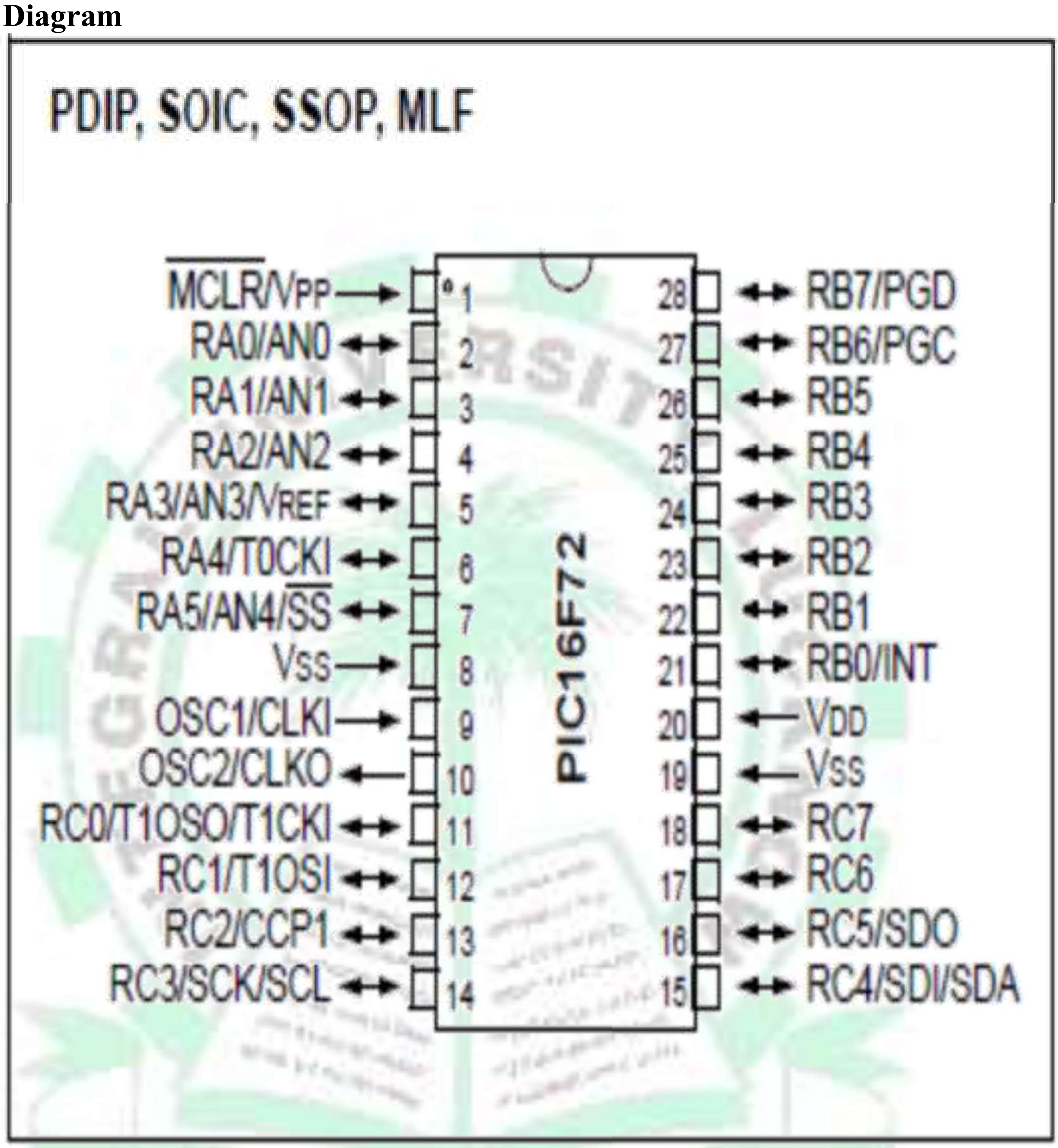
Step-3: Connect the positive power rail to the terminal strip via a 1K ohm resistor

Step-4: Fix the LED to the ports below the resistor connection in the terminal strip

Step-5: Close the circuit by connecting the cathode (the short chord) of the LED to the negative power strip of the breadboard

4.5 DETAILS OF MICROCONTRLLER

A) Pin Diagram



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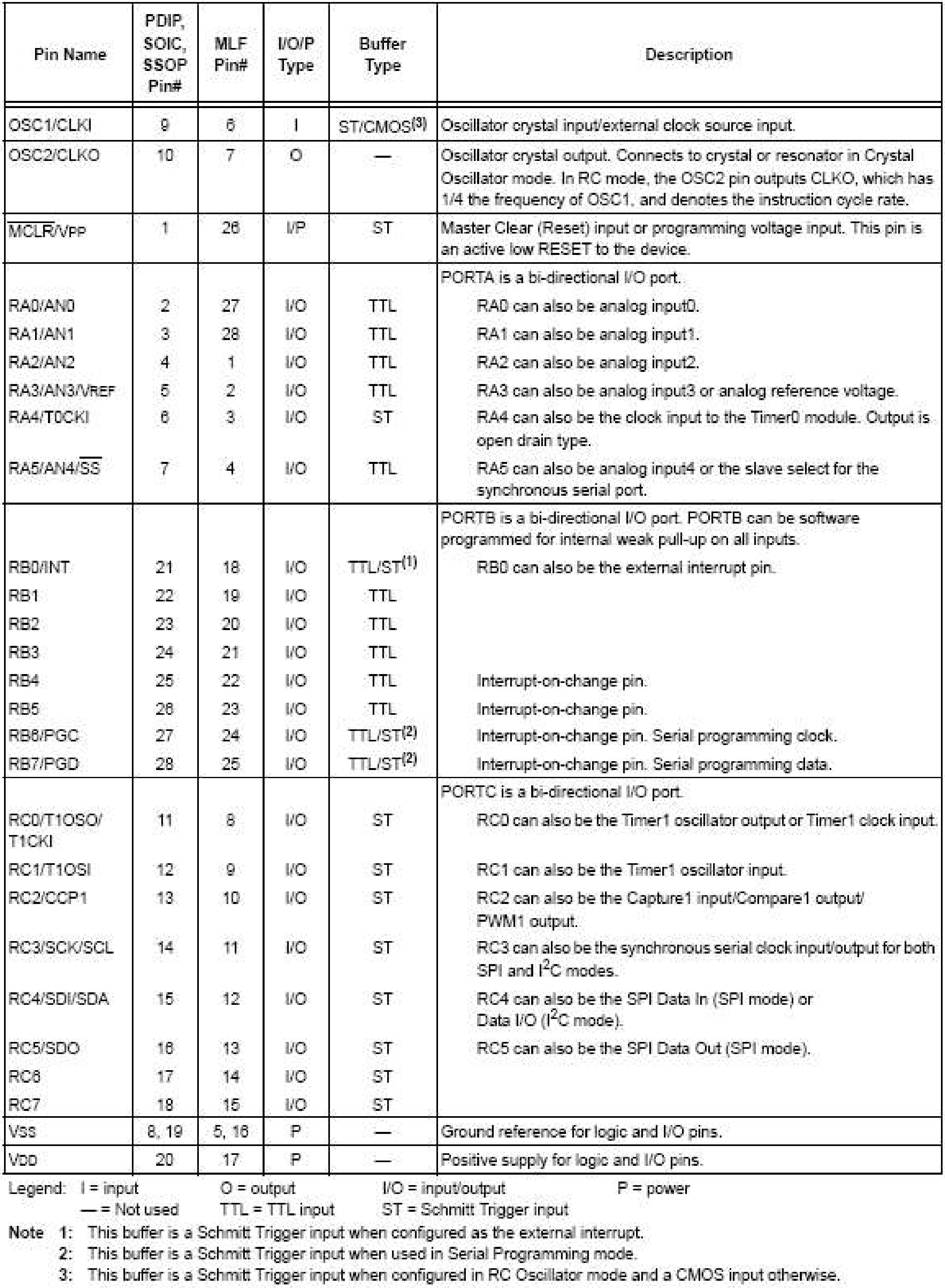
B) Pin Description

Following table shows the pin description of microcontroller:

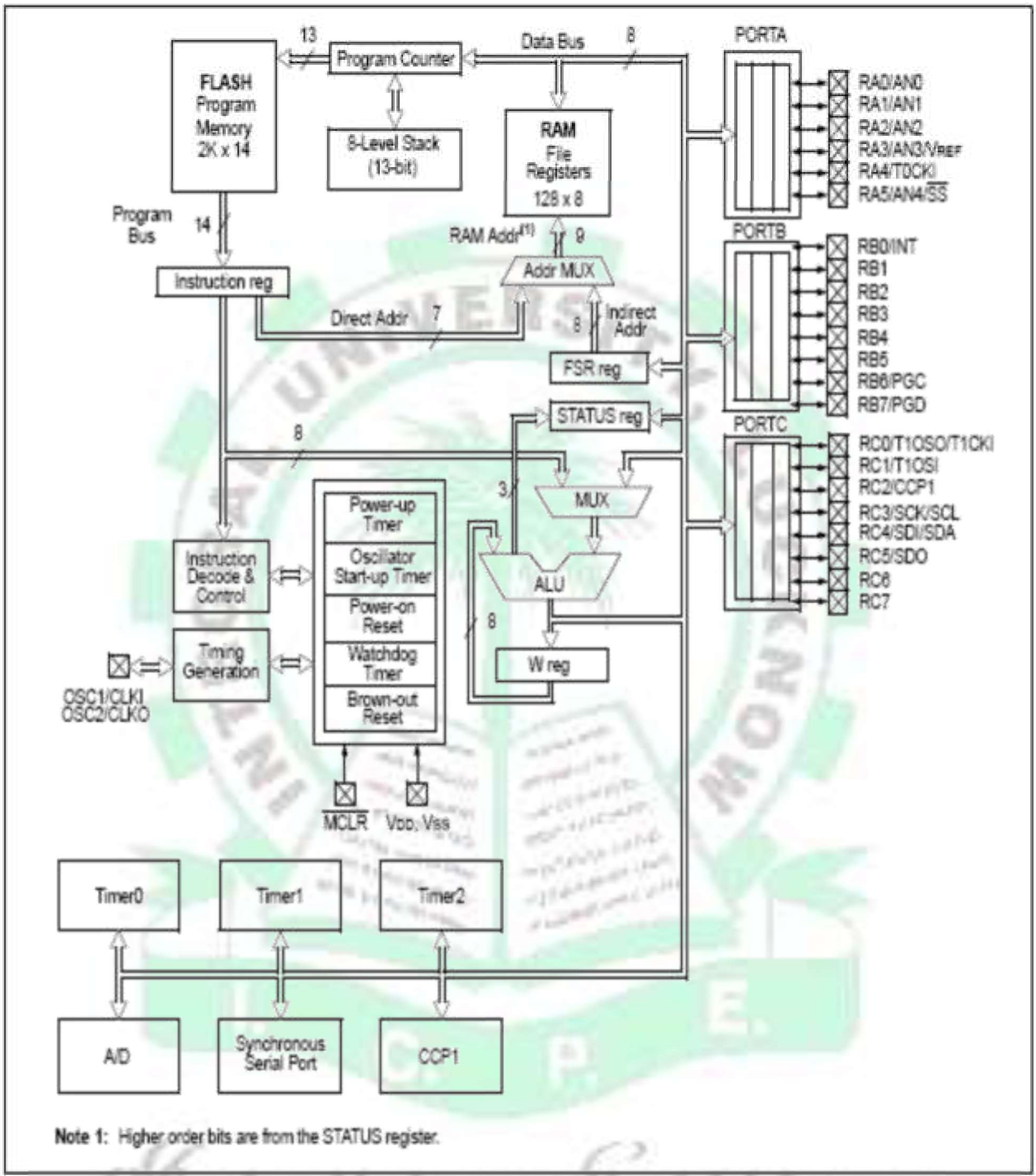


Pin Name	PDIP, SOIC, SSOP Pin#	MLF Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKI	9	6	I	ST/CMOS$^{(3)}$	Oscillator crystal input/external clock source input.
OSC2/CLKO	10	7	O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode. In RC mode, the OSC2 pin outputs CLKO, which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	1	26	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
					PORTA is a bi-directional I/O port.
RA0/AN0	2	27	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	28	I/O	TTL	RA1 can also be analog input1.
RA2/AN2	4	1	I/O	TTL	RA2 can also be analog input2.
RA3/AN3/VREF	5	2	I/O	TTL	RA3 can also be analog input3 or analog reference voltage.
RA4/T0CKI	6	3	I/O	ST	RA4 can also be the clock input to the Timer0 module. Output is open drain type.
RA5/AN4/$\overline{\text{SS}}$	7	4	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
					PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	21	18	I/O	TTL/ST$^{(1)}$	RB0 can also be the external interrupt pin.
RB1	22	19	I/O	TTL	
RB2	23	20	I/O	TTL	
RB3	24	21	I/O	TTL	
RB4	25	22	I/O	TTL	Interrupt-on-change pin.
RB5	26	23	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	27	24	I/O	TTL/ST$^{(2)}$	Interrupt-on-change pin. Serial programming clock.
RB7/PGD	28	25	I/O	TTL/ST$^{(2)}$	Interrupt-on-change pin. Serial programming data.
					PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	11	8	I/O	ST	RC0 can also be the Timer1 oscillator output or Timer1 clock input.
RC1/T1OSI	12	9	I/O	ST	RC1 can also be the Timer1 oscillator input.
RC2/CCP1	13	10	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	14	11	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^{2}C modes.
RC4/SDI/SDA	15	12	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or Data I/O (I^{2}C mode).
RC5/SDO	16	13	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6	17	14	I/O	ST	
RC7	18	15	I/O	ST	
VSS	8, 19	5, 16	P	—	Ground reference for logic and I/O pins.
VDD	20	17	P	—	Positive supply for logic and I/O pins.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as the external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured in RC Oscillator mode and a CMOS input otherwise.

C) Block Diagram



Note 1: Higher order bits are from the STATUS register.

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4.6 BLYNK APP

Blynk is not an app that works only with a particular shield. Instead, it's been designed to support the boards and shields you are already using. And it works on iOs and Android. UPD: Blynk also works over USB.

According to Blynk's website, “Blynk is a Platform with iOS and Android apps to control Arduino, Raspberry Pi and the likes over the Internet. It's a digital dashboard where you can build a graphic interface for your project by simply dragging and dropping widgets.

A platform differences seen earlier blynk is a solution for building IoT applications available for Android and iOS. Based on platforms known as Arduino, Raspberry pi, ESP8266, Intel Galileo, Particle, Serial devices and Wifi among others, in a few minutes you can create a high quality dashboard, we highlight the large number of available widgets, Control, display, Notification and Video Steaming. In this case we will perform the Tests with Module ESP8266 in the following tuturial show step by step installations and configurations for the Blynk application.

In this project we use ESP8266 12E Node MCU from the library of Arduino UNO & module is programmed by using PC.

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Chapter 5: CONCLUSION & FUTURE SCOPE 25-26

5.1 CONCLUSION 25

5.2 FUTURE SCOPE 26

CHAPTER 5 CONCLUSION AND FUTURE SCOPE

This chapter is the valedictory of our project thesis in which we wrote the final conclusion of our Project illustrating the result along-with the short discussion about the future scope of our presented model.

5.1 CONCLUSION:

When load requirement increases or decrease than particular RELAY of desired voltage is operated and a Power Line can be easily turn on/off through mobile phone from anywhere in the world as per the requirement.

This variation in line voltage of the power system is dependent upon the load change which depends upon the load requirement of load connected at consumer end.

Blynk command instruction is passed on the respective relay, according to the command respective relay is on and required grid channel is get selected so that it can turn off the power supply when it exceed the critical voltage limit of the grid interconnected power.

We have successfully completed the project of Grid Interconnected Power System Controlled by using Internet. Through this project we conclude that any grid interconnected power system can be easily controlled by using IoT Technology.

Anyone can operate this from anywhere in the world as per the requirement.

The developing of this project has been a learning experience of IoT for all team members and would prove as a first milestone in our academic career. Achievements of our project work are:

i. The project has achieved its set target well in “Time” and “Budget”.
ii. We have learnt “How to work in Team”
iii. Based on IoT technology which is coming in future market and its future is much bright.
iv. The Grid interconnected Power system has been studied as to control each grid/chennal individually in practical applications.

So, we conclude that the IoT control of grid interconnected power system is still far away from the perfect, but we believe that we have laid the groundwork to show an educational model which is the combination of Power System, Network System & Control System through IoT technology.

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5.2 FUTURE SCOPE

As we know that the power system is converting towards smart power system by using various advance technologies in modern era. This IoT controlled model is a system that can prove to be very beneficial in the future because in the case of increasing demand of smart technology to minimize man power along-with the reducing the manual switching work in Power System Engineering.

When the load requirement increases or decreases then voltage variation occurs at consumer end of the power system. This variation in output voltage that is increasing or decreasing voltage is dependent upon the load change which may be detected by IoT after the further advancement of this project in future So as to control the switching effectively along with tracking & monitoring all electrical variations in any power System network Online.

The load on any grid, the device used in a system can detect overvoltage problems in these interconnected power systems. Thus loss of millions of rupees in the case of voltage variation in any system can be avoided without the physical presence at Control Room of respective grid/chennal.

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BASE PAPER

SPECIAL SECTION ON INTELLIGENT AND COGNITIVE TECHNIQUES FOR INTERNET OF THINGS

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Internet of Things Based Smart Grids Supported by Intelligent Edge Computing

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ABSTRACT In this paper, an edge computing system for IoT-based (Internet of Things) smart grids is proposed to overcome the drawbacks in the current cloud computing paradigm in power systems, where many problems have yet to be addressed such as fully realizing the requirements of high bandwidth with low latency. The new system mainly introduces edge computing in the traditional cloud-based power system and establishes a new hardware and software architecture. Therefore, a considerable amount of data generated in the electrical grid will be analyzed, processed, and stored at the edge of the network. Aided with edge computing paradigm, the IoT-based smart grids will realize the connection and management of substantial terminals, provide the real-time analysis and processing of massive data, and foster the digitalization of smart grids. In addition, we propose a privacy protection strategy via edge computing, data prediction strategy, and pre-processing strategy of hierarchical decision-making based on task grading (HDTG) for the IoT-based smart girds. The effectiveness of our proposed approaches has been demonstrated via the numerical simulations.

INDEX TERMS Edge computing, IoT-based smart grids, data prediction, artificial intelligence, data privacy protection, cloud computing.

I. INTRODUCTION

With the supports of some new technologies, such as edge computing, big data, the 5-th generation wireless technologies (5G), IoT, and artificial intelligence (AI), smart grids have been regarded as important research topics. How to apply these new technologies to conventional power systems and establish smart grids have attracted extensive research efforts from industries and academia [1]–[3]. Conventional power systems mainly include power generations, power transformations, power transmissions, and power distributions. There are various types of power terminals and sensors in smart grids, for instance, humidity sensors, temperature sensors, immersion sensors, vibration sensors, current leakage sensors, intelligent video sensors and so on, which can support IoT based intelligent power systems [4], [5]. In this typical scenario where IoT technologies are applied to power systems, key charateristics of smart grids can be significantly improved such as data visualizations, load forecasting, failure prediction, and self-healing. As a result the optimum power systems operation and management can be achieved [6], [7]. Up to now, there are a number of technical challenges still to be further studied for IoT deployment in smart grids.

1) The transformation from traditional power systems to smart grids will encounter a large number of technical challenges. Hence, it is necessary to achieve data standardization and data fusion for establishing a digital transformation of power systems.
2) According to the statistics of the China Electricity Council, mismatches between power supply and power sales always happen in power systems, and the transmission line losses are large [8]. As shown in Fig.1 and 2, from 2010 to 2017, there still exists wide gap between power supply and power sales, and the line losses are generally on the rise. On the basis of statistics on the electricity consumptions of the whole society,

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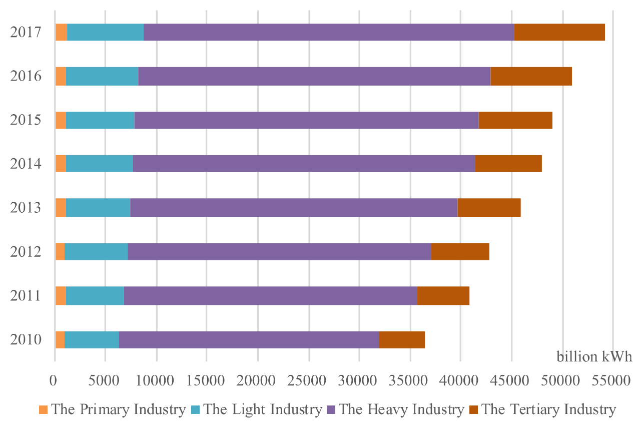

FIGURE 1. Imbalance between power supply and power sales.

the electricity consumptions vary greatly among different industries, especially between the primary industry and heavy industry. However, the present power systems cannot be deployed in real time to satisfy consumer's electricity demands [9], [10].

3) With the emergence of an increasing number of new intelligent distributed power terminals, it is necessary to achieve the plug-and-play and interoperability among devices.

Although current cloud-based power systems can partially solve these problems, they still cannot fully meet these requirements, and also bring about new challenges. The main relevant issues include:

1) The cost is high since the cloud computing should be equipped with large data center. Meanwhile the maintenance of centers is arduous and requires high transmission bandwidth.
2) Traditional cloud architecture requires high-speed processing and large-scale data storage capacities, without effective real-time services.
3) Cloud data centers of smart girds have difficulties in processing and analyzing tremendous data in an effective and real-time manner.
4) When a single node in a power systems fails in an actual metering system, several problems about how to upload data of all faulty devices to the cloud for analyses remain unresolved. First, the resolution time is long, but the cost is high. Second, many data need to be uploaded which requires high transmission bandwidths in communication networks.

Recently the general discussions discovering the relations between big data and environmental sustainability relevant green challenges have been provided in [11], [12], while the relationship between big data and cyber-physical systems (or IoT) has still been a open problem in the electricity sector. [13]. To solve these issue, the new system mainly introduces edge computing in the traditional cloud-based power systems, establishing a new software and hardware architecture. It deploys an edge computing paradigm for smart grids, which includes control, condition monitoring, information gathering, and application scenario of IoT-based smart grids. With the realization of parallel processing and analysis of data from various collection terminals, smart devices and end-users of smart grids at the edge of network, the distributed fast response services and edge intelligent services such as data prediction, privacy protection, resource allocation optimization will be provided. The advantages for the adoption of edge computing are as follows:

- **Low latency:** Edge computing process the demands of users within close proximity to the terminals, which may alleviate service latency and offer intelligent decisions.
- **Customization of personal needs:** In the metering system, the edge computing devices statistically analyse the electricity consumptions of users, thereby dynamically adjusting the power supply of each electricity consumption area and formulating a reasonable economic and energy-saving transmission and distribution scheme.
- **Decentralization:** In distributed power systems, the presence of the edge computing devices alleviate the burden on the network core nodes of the cloud computing terminals for the power systems and weaken their dependency on the cloud centers.
- **Geographical distribution:** Distributed deployment of edge computing devices can help high-speed mobility devices such as unmanned aerial vehicles for inspecting transmission lines to have better communications with each other.
- **Location awareness:** The edge computing devices can promote resource management to provide local decision-making for power transmissions.

The rest of paper is organized as follows. Section II addresses related works about IoT-based smart grids and edge computing. Section III illustrates the architecture of edge computing for IoT-based smart grids, which includes power distribution surveillance system for EC-IoT based smart grids, microgrid system of EC-IoT smart grids, and Advanced metering system of EC-IoT smart grid. Then, applications of edge computing in IoT-based smart grids are described in section IV. We elaborate data security and privacy protection, dynamic pricing prediction and hierarchical decision-making based on task grading (HDTG) in EC-IoT based smart grids. Numerical results were presented in Section V. Finally, we conclude the paper as well as discuss the further works in Section VI.

II. RELATED WORKS

In this section, we first provide an overview of existing works in IoT-based smart grids, and then introduce the concept of edge computing.

A. IoT-BASED SMART GRIDS

IoT-Based smart grids are considered as the critical infrastructure in future [14]. With the development of 5G technologies, IoT has been of great importance to people's daily life. Integrating smart devices, information technologies, communication technologies, and artificial intelligences into traditional power systems becomes promising. At present,

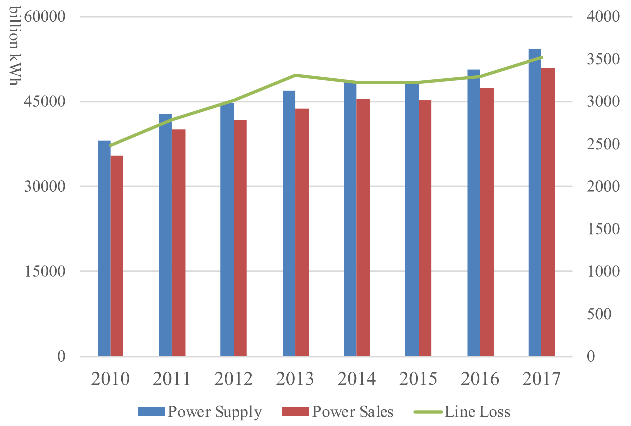

FIGURE 2. Total electricity consumptions.

the key to implement these technologies is how to build a new network structure of power systems to meet the physical layer construction of these new inventions. Obviously, the emergence of IoT-based smart grids has opens up possibilities to the realization of these technologies.

IoT-Based smart grids is a new form of network with deep integration of traditional industrial technology and IoT technologies. [4], [5]. The IoT-based smart grids may include six emblematical characteristics:

1) Plug-and-play for all kinds of terminals,
2) Wide interconnection of devices,
3) Comprehensive awareness of status of smart grids,
4) Upgraded application mode of power systems,
5) Rapid iteration of services in power systems,
6) Efficient use of electric distribution system.

The advantages of IoT-based smart grids are to realize the comprehensive sensing, data integration and intelligent application of the distribution network by utilizing the comprehensive interconnection, intercommunication and interoperability between devices in the system. It aims to meet the demand for excellence in power system management and support the rapid advancement of the energy internet, as well as achieve intelligent allocation of power resources. [15]–[17].

In order to realize the IoT-based smart grids, six fundamental technologies need to be developed, including model protocols, software-defined devices, edge computing-based application analysis, intelligent sensing technology, network information security technology, and low-cost and a wide coverage area local communication technologies. Among them, edge computing is the most important core technology to achieve real-time demand response of IoT-based smart grids and various types of edge intelligent services. The challenges for cyber-security of cyber-physical systems (or IoT) have been analyzed in [18].

B. EDGE COMPUTING IN IoT NETWORKS

Edge computing is a technology developed in the context of high bandwidth and time sensitive IoT integration. In the future, more than 50% of data need to be analyzed, processed and stored at the edge of the network [19]. As devices access the Internet of Things in large scale, the massive volumes of data generated on the terminals can provide commercial values but are very challenging in data processing. Owing to the limited network bandwidths and the real-time response requirements, edge computing has been considered as one of the new technical trends for the development of IoT [20]. Edge computing, providing an information technology (IT) service environment and extra cloud-computing capabilities, can be deployed at the edge of radio access networks (RAN) in close proximity to mobile subscribers [21]. The application of edge computing has been recognized as a significant means to achieve efficiency of network operations and latency reduction for better end user experience. It also satisfies the needs in terms of agile connectivity, real-time services, data optimization, application intelligence, and privacy protection. [22], [23].

Therefore, edge computing could be widely applied in smart cities, intelligent transportation, health care, smart manufacturing, smart home, and other application areas [24]. In particular, issues including smart grids related with edge network, demand response and energy-saving transmission have attracted heated discussions both in academics and industries [25]–[30]. As there are numerous power sensor nodes in the IoT-based smart grids, these devices need to process the data sources at the edge of networks to meet the real-time demand responses, such as real-time local electric distributions, transmissions, and accident alarms. With edge computing, there is no need to upload the edge data to a remote cloud network for analysing and processing, leading to delayed responses. In this case, an open platform for connection, computing, storage and application is needed at the edge of the network close to the object or data source, which can provide edge intelligent services for the data of the power sensor nodes. Meanwhile, considering that data are no longer necessarily transmitted over distant networks, the security and stability of the system is more controllable.

III. ARCHITECTURE OF EDGE COMPUTING FOR IoT-BASED SMART GRIDS

In this section, we present the system of IoT-based smart grids. Then we will introduce the specific services of IoT-based smart grids supported by edge computing, which are applied to the three main scenarios, including power distribution surveillance systems of EC-IoT smart grids, micro-grid systems of EC-IoT smart grids, and advanced metering systems of EC-IoT smart grids.

As shown in Fig. 3, in the three typical scenarios of smart grids, the applications of IoT and edge computing technologies make intelligence and automation of power systems enter into a new stage. parallel processing and analysis of data from various collection terminals, smart devices and end-users of smart grids can be realized at the edge of network via deploying the edge computing model for the smart grids with supporting technologies such as micro-super-computing, data fusion, multi-agent and deep learning, providing a distributed

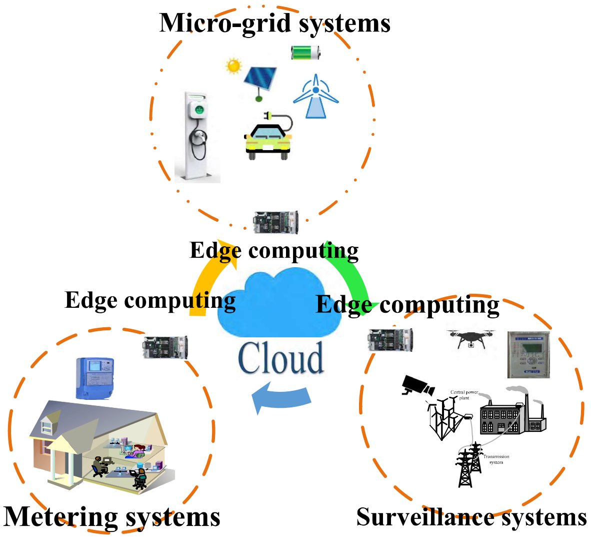

FIGURE 3. Architecture of edge computing for IoT-based smart grids.

information computing service with large volumes of data and fast responses. Under such circumstance, this mode can satisfy the demand of rapid responses required by devices and users in the smart grids and provide supports for advanced applications of smart grids such as intelligent scheduling, intelligent maintenances, intelligent user responses, and rapid market responses.

This paper proposes an edge computing hardware and software architecture for power systems, which combines with the reference architecture of industrial edge computing [31], and consists of five layers as shown in Fig. 4 and explained briefly as follows:

1) **Device layer:** Devices generally include applications, security modules, networks, security operating systems, and core control chips.
2) **Network layer:** The network layer satisfy the demand of rapid responses required by devices and users as network security, access control, and real-time terminal connection.
3) **Data layer:** The data layer mainly provides data security, data analysis, data privacy protection, and data fusion functions.
4) **Application layer:** Application layer primarily covers application security, intelligent edge services, and edge computing applications.
5) **Cloud computing layer:** Cloud computing layer typically offers services, such as SaaS (software-as-a-service), PaaS (Platform-as-a-service), IaaS (Infrastructure-as-a-service), and DaaS (Data management as a service).

Among them, edge computing devices, on the basis of the hardware platform, mainly have a network layer, a data layer, and an application layer. In addition, the network management module, the computing management module, and the memory management module are also contained. The edge computing devices can also ensure the secure access of various terminals in the device layer and keep themselves and cloud computing layer to work collaboratively through application programming interfaces (API).

The power terminals and various types of sensing devices in the equipment layer can be connected with the edge computing devices through two approaches, a wireless (such as WiFi, buletooth, ethernet, 3G/4G wireless) network and a wired network. The reference architecture can provide edge

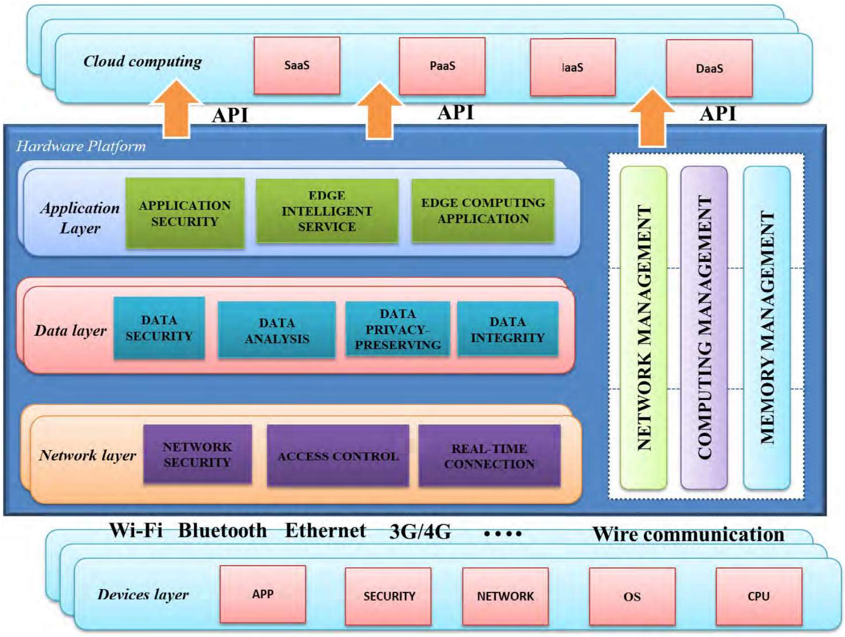

FIGURE 4. Edge computing reference architecture for IoT-based smart grids.

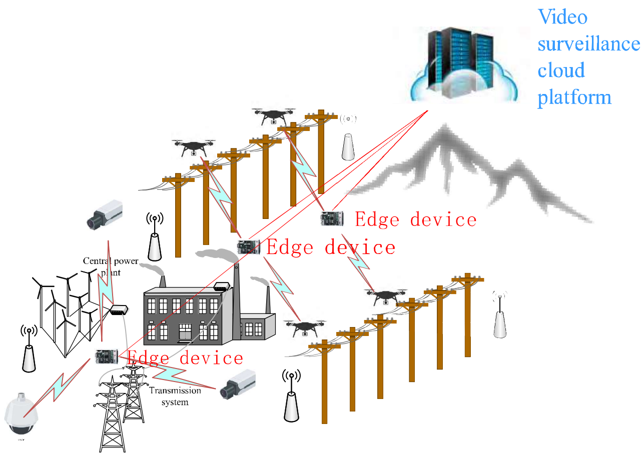

FIGURE 5. Power distribution surveillance system of EC-IoT smart grids.

intelligent services in close proximity to users so as to achieve digitization of power systems. In this regard, it will give prominence to the advantages of edge computing in agile connections, real-time services, data optimization, application intelligences, cloud collaborations, and localized computing.

The power distribution surveillance system is mainly composed of state detection and video surveillance of the transmission and distribution networks, which plays the roles of remote control, telemetry and remote signaling. Operation status of the transmissions and distribution processes can be fully mastered in time through real-time collection and display of various operating switch states and power parameters during generations, transmissions, and conversions of power. More importantly, faults can be found promptly, and corresponding decisions can be made and dealt with [32], [33]. The edge computing-based power monitoring system adds edge computing device nodes to the traditional cloud-based power monitoring system. The device nodes can implement agile control, data storage, and application of edge computing, and meanwhile process some real-time response locally without uploading data to the cloud. Moreover, other characteristics that benefit the devices own in the system include real-time analyses of power loads in local areas, reasonable scheduling of power consumptions, and fast responses to the distribution and transmission system.

The Fig. 5 mainly describes the two service applications of intelligent inspection for transmission lines utilizing unmanned aerial vehicles and video surveillance in the power monitoring system based on edge computing.

A. POWER DISTRIBUTION SURVEILLANCE SYSTEM FOR EC-IoT BASED SMART GRIDS

1) TRANSMISSION LINE MONITORING BY UNMANNED AERIAL VEHICLE

Deployed in local areas, edge computing device nodes can perform data interactions with groups of unmanned aerial vehicles when they fly into the regions under the control of edge computing networks. Then, through real-time processing information, offline information, end-users' information, parameters of electrical structure of power grids, and geographic information gathered by inspection of unmanned aerial vehicles, preliminary judgment of the accident level and real-time processing feedbacks can be provided. In the event of a natural or man-made failure, it is possible to effectively control and eliminate the adverse consequences caused by failures in a timely manner while maintaining the stable operations of the grid system. Simultaneously, the edge computing devices can also aggregate the relevant conditions and upload the situation to the cloud computing center to realize panoramic and long-term data accident analyses.

2) VIDEO SURVEILLANCE

Deployed in substations, edge computing device nodes can be integrated with system services such as anti-misoperation, transmission line monitoring, power transmission and transformation surveillance, electric brakes monitoring for abnormality, and power dispatching automation. They support accesses to multiple monitoring devices and can be set in different substations as needed. Besides, the devices at the edge of the network realize the unified terminal management of video data, environmental data, power data and alarm data, which ensures the warnings before events, the suppression during events, and the reviews after events.

Compared with the traditional cloud architecture, the edge computing-based power monitoring system has the advantages of short delays, fast local response time, data filtering and pre-processing. It is not necessary to transmit every original data to the cloud, which reduces the needed transmission bandwidth for direct uploading to cloud and reduce transmission costs. In addition, the system will work with the cloud according to the amount of data and the complexity of the architecture. For example, edge computing can be used as a collection unit of cloud data to support big data analysis of cloud applications, while cloud computing can feedback the optimized information to the terminal through big data analysis, and then makes further processing through edge computing. Edge computing can realize the quick responses in light of the situation scale to attain the efficient and stable operations of the smart grids.

B. MICRO-GRID SYSTEM OF EC-IoT SMART GRID

The micro-grid system is a small-scale power distribution system consisting of distributed power sources, energy storage devices, energy conversion devices, and devices for electrical load, monitoring and protection. It aims to implement flexible and efficient application of distributed power supply and tackle the problem of interconnection between massive and diverse distributed power supplies. The development and extension of the microgrids can fully promote the large-scale access of distributed power and renewable energy as well as achieve highly reliable supplies of multiple forms of energy sources. This is an effective way to establish a proactive electric distribution system, making the transition from traditional grids to the smart grids [34]. The micro-grid system of EC-IoT smart grids is set on the foundation of

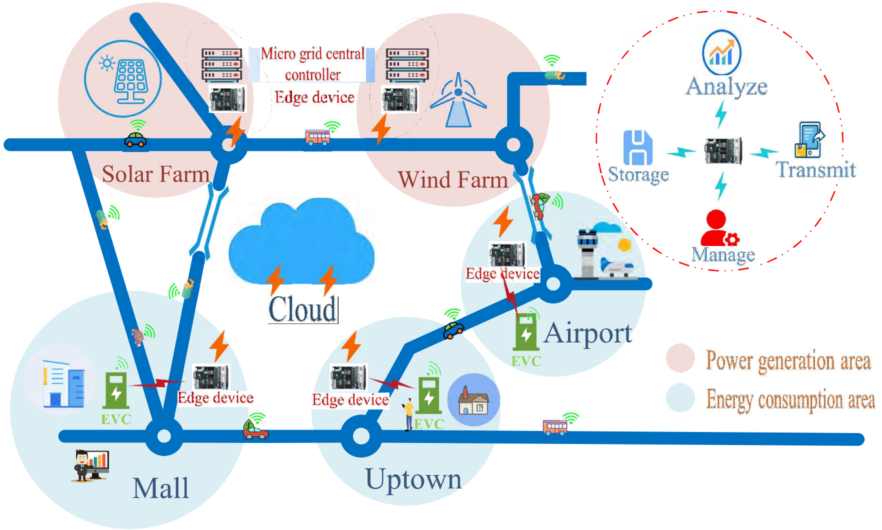

FIGURE 6. Micro-grid system of EC-IoT smart grids.

cloud-based renewable energy micro-grid system. Its control center and the edge computing devices are taken as local edge computing nodes to establish a real-time edge service scenario on the demand side for the electricity consumptions within the area.

Fig. 6 mainly depicts the two scenarios of edge computing applied in smart grids, namely, power supply management of charging points, and power balance and identification of malicious behaviors in electricity consumptions.

1) POWER SUPPLY MANAGEMENT OF CHARGING POINTS

Charging point is a boundary point for integrating power systems, information networks, and transportation networks. Large-scale attacks can lead to drastic fluctuations in power systems and traffic congestion. The local edge computing nodes can analyze the features and the consumption mode in consuming electricity of the charging points and memorize the features. Besides, it can analyse the sudden fluctuations of power consumptions, and balance the dynamic features of local power consumptions. For sudden, malicious, and aggressive power fluctuations, edge computing can identify them and report the results to the cloud management center.

2) IDENTIFICATION OF MALICIOUS BEHAVIORS IN ELECTRICITY CONSUMPTION

The edge computing devices collect the photovoltaic power generation in real time from micro-network central controller and grid-connected interface controller of distributed power supplies, and establish the electricity generation behavior mode of each device, which is characterized by quantity of electricity and time of the photovoltaic power generation equipment. Correspondingly, these devices use the power consumption behaviors of users in the micro-network as parameters to build the electricity behavior mode and identify the power balance and malicious behavior of the smart energy.

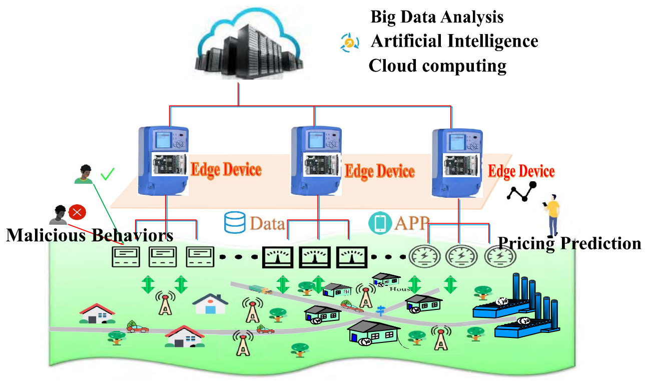

FIGURE 7. Advanced Metering system of EC-IoT smart grids.

C. ADVANCED METERING SYSTEM OF EC-IoT SMART GRID

The advanced metering system can realize automatic collection, remote transmission and storage, and pre-processing of electricity consumption data, ensuring the reliability, uniqueness, accuracy and continuity in the process of collecting, transmitting, and processing these data. The advanced metering systems for EC-IoT smart grids lay out edge computing devices in power meter concentrators within traditional cloud-based metering systems. Those edge computing devices mainly are equipped with the functions of edge computing application service analyses, data storage, and data analyses. The system can achieve real-time responses on the demand side in power meter concentrators based on edge computing. The Fig. 7 mainly represents the architectural features of the system. At the metering client side, their own power usage information is first uploaded to the centralized metering device with edge computing capability through wired and wireless communication. And then power metering service based on the edge computing service can be implemented. For instance electricity price forecasting in metering systems (dynamic pricing prediction) and identification of malicious behaviors in electricity consumptions. Through collecting the information about power usage recorded in electricity meter and then predicts the real-time electricity price under the national pricing constraints. The predicted price will be sent to the user through the APP to select the power usage time. In this way, it is expected to realize friendly interactions between power supply and consumers. The power meter concentrators with edge computing take the information of power consumption and usage time recorded by each meter as parameters to establish the power consumption behaviors. Also, they will identify the sudden or phased changes in the use of electricity and evaluate damages towards the grids due to abnormal changes. Finally, these data will be reported to the cloud management center.

Compared with the traditional cloud-based metering system, metering system of EC-IoT smart grids can realize accurate real-time electricity price forecasting, localize real-time analysis of application service in smart grids, optimize resource allocation scheme, improve reading efficiency of metering system and cut costs. In particular, in the edge computing device layer, metering system can achieve terminal compatible access, information sharing transparency, integrated standard specification, and facilitate the synergy and interoperability of information management service in power systems. Furthermore, the system has a role play in reliable data storage and optimization management for massive user electricity and power grid data. As a whole, the intelligent analyses of grid data and accessory decision supports can be improved by means of fully exploiting the potential values of information.

IV. APPLICATION OF EDGE COMPUTING IN IoT-BASED SMART GRIDS

In this section, we will present the typical applications and the related advantages brought by the architecture based on the three scenarios of the EC-IoT grid system. Depending on features of edge computing, users' data privacy can be protected, meanwhile dynamic power price forecasting in advanced metering systems can be provided. Furthermore, hierarchical task real-time processing response strategies will be achieved for electricity users' timely demand response.

A. DATA SECURITY AND PRIVACY IN EC-IoT BASED SMART GRID

Privacy is information that individuals and institutions are unwilling to be known by others. In general, it refers to sensitive data, such as illnesses, bank card numbers, and so on. The user privacy of the advanced metering system is mainly presented by their personal information, such as the ID number, contact information, and electricity-consumption habits. In IoT-based smart grids, some people with ill-intentions can obtain user privacy through data mining technologies. In order to solve this problem, on account of the features of edge computing, we propose a differential privacy data distortion technique based on Laplace mechanism and Gaussian mechanism.

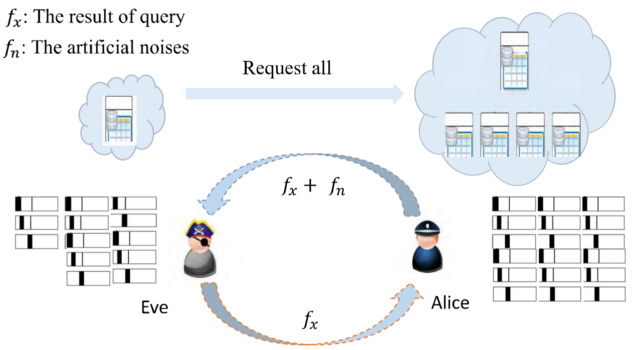

FIGURE 8. Attack model of interactive data access.

The proposed technology is implemented by edge computing devices, in which artificial noises are added to the power consumption data of each smart meter, thus hiding the electricity behavior model and avoiding leakage of privacy. We first introduce the Laplace differential privacy mechanism before elaborating on the Gaussian differential privacy mechanism, both of which can be used for data privacy protection. Differential privacy protection protects sensitive data by adding artificial noises, while ensuring that the data retains the same statistical characteristics as the original data set after adding the artificial noises, making the published data meaningful and facilitating data mining [35].

We establish an attack model of interactive data accesses as shown in Fig. 8. Eve is the attacker and Alice is the publisher of a database. First, Eve is disguised as the legal identity and initiates a request for querying the database to Alice. After Alice implements the privacy protection towards the query result, she sends it to Eve. Hypothesizing that the attacker Eve gets the original sensitive data set that are very similar to the real data set owned by Alice (in the worst case, for example, the data set of attacker Eve are only different from the real data set in one piece of information), the privacy protection method still needs to ensure that the attacker Eve cannot obtain sensitive content of this information regardless of what are the adopted methods. According to the attack model, the mathematical definition of differential privacy is: A randomized algorithm H with domain $\mathbb{N}^{|\chi|}$ is (ε, δ) differentially private if for all $T \subseteq Range(H)$ and for all $x, y \in \mathbb{N}^{|\chi|}$such that $\|\mathrm{x}-\mathrm{y}\|_1 \leqslant 1$:

$$\Pr[H(x) \in T] \leq \exp(\varepsilon) \Pr[H(y) \in T] + \delta \tag{1}$$

where ε stands for privacy budget as security indicator. The smaller the indicator ε is, the higher the security level will be.

Algorithm 1 Laplace Mechanism

```
Input: a private database X, an adaptively chosen stream of sensitivity $l_1$ queries $g_1 ... g_j$.
Output: an adding noise database $\hat{X}$.
LM $(x, \{g_i\}, \varepsilon, \sigma)$.
Calculate the $\Delta_1 g$, using formula (2).
Calculate the scale parameter $b = {}^{\Delta_1 g}/_{\varepsilon}$.
Calculate the noise $N = \frac{1}{2}(1 + sgn(x)(1 - \exp(\frac{|x|}{b})))$.
Calculate the adding noise database $\hat{X} = X + N$.
Output: $\hat{X}$.
```

1) LAPLACE MECHANISM

We firstly define sensitivity, an essential concept in this mechanism. Specifically, it refers to the degree of impact on the results of our query after the artificial noise is added to the data set that needs privacy protection.

The l_1 sensitivity of a function g: $\mathbb{N}^{|X|} \rightarrow \mathbb{R}^k$ is:

$$\Delta_1 g = \max_{\substack{x,y \in \mathbb{N}^{|X|} \\ \|x-y\|_1 = 1}} \|g(x) - g(y)\|_1 \tag{2}$$

The Laplace distribution is the distribution with probability density function:

$$Laplace(x|b) = \frac{1}{2b} \exp(-\frac{|x|}{b}) \tag{3}$$

Given any function $g(x)$:$\mathbb{N}^{|X|} \rightarrow \mathbb{R}^k$, the Laplace mechanism is defined as:

$$M_L(x, g(x), \varepsilon) = g(x) + (Y_1, \ldots, Y_k) \tag{4}$$

where Y_i are independent and identically distributed (i.i.d.) random variables drawn from $Laplace(\Delta_1 g/\varepsilon)$. This mechanism preserves $(\varepsilon, 0)$ -differential privacy. Algorithm 1 implements a privacy protection method based on the Laplace noise mechanism, which uses sensitivity l_1 and the query function, $g_j(x)$. After the queries of users, scale parameter b, the artificial random noise of Lap(b), is added to the feedback result and generated $\hat{X}$, thereby achieving differential privacy protection for in the privacy data of set X.

2) GAUSSIAN MECHANISM

Gaussian noises are very commonly used in modeling communication systems. Similarly, we can also implement privacy protection by adding artificial Gaussian mechanism noises, but, if this mechanism is adopted, we need to have some conditional restrictions, and to broaden the definition of differential privacy. Again, in the same way as Laplace, we first define the sensitivity, here the l_2 sensitivity is applied:

The l_2 sensitivity of a function g: $\mathbb{N}^{|X|} \rightarrow \mathbb{R}^k$ is:

$$\Delta_2 g = \max_{\substack{x,y \in N^{|X|} \\ \|x-y\|_1 = 1}} \|g(x) - g(y)\|_2 \tag{5}$$

The Gaussian distribution is the distribution with probability density function:

$$Gaussian(x|\mu, \sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp(-\frac{(x-\mu)^2}{2\sigma^2}) \tag{6}$$

Given any function $g(x)$: $\mathbb{N}^{|X|} \rightarrow \mathbb{R}^k$, the Gaussian mechanism is defined as:

$$M_L(x, g(x), \varepsilon) = g(x) + (Y_1, \ldots, Y_k) \tag{7}$$

where Y_i are i.i.d. random variables drawn from Gaussian distribution $\mathcal{N}(x|0, \sigma^2)$, $c^2 > 2\ln(\frac{1.25}{\delta})$, and $\sigma > \frac{c\Delta_2 g}{\varepsilon}$. This mechanism preserves (ε, δ)-differential privacy. Algorithm 2 implements a privacy protection method based on the Gaussian mechanism, which uses sensitivity l_2 and the query function, $g(x)$. After the queries of users, the normal distribution random noise of the scale parameter $N(0, \sigma)$ is added to the feedback result and generated $\hat{X}$, thus achieving differential privacy protection for $(\varepsilon, \delta = 0)$ in the privacy data of set X. The values of ε and c are strictly defined, otherwise the differential privacy cannot be satisfied.

Algorithm 2 Gaussian Mechanism

```
Input: a private database X, an adaptively chosen stream of sensitivity $l_2$ queries $g_1 ... g_j$. Privacy budget $\varepsilon$, $\delta$, $\sigma$, constant $c$.
Output: an adding noise database $\hat{X}$.
$GM(X, \{g_i\}, \varepsilon, \delta, \sigma, c)$.
Let $\Delta_2 g$, using formula (5).
If $0 < \varepsilon < 1$.
    If $c^2 > 2\ln(1.25/\delta)$.
        Let $\sigma \geq c\Delta_2(g)/\varepsilon$.
        $N = \frac{1}{2}(1 + sgn(x)(1 - \exp(\frac{|x|}{b})))$.
        Let $\hat{X} = X + N$.
        Else halt.
    End if.
Else halt.
End if.
Output $\hat{X}$.
```

B. DYNAMIC PRICING PREDICTION IN EC-IoT BASED SMART GRIDS

Whether the power supply and power sales can achieve the optimal supply and demand relationship is an unresolved issue of the power grid company nowadays. Similarly, it is also important for power consumers to be informed that how they can exploit reasonable power consumption schemes to meet daily expenses and achieve cost savings. To satisfy these demands, edge computing-based real-time data prediction algorithms can be adopted.

Whatever a power consumer or a power grid company is, all power consumption is generated in time series. According to the prediction of the time series, the electricity consumption will vary in line with the influence of the time period. For these time series, there is some correlation in a certain sense.

It is necessary to find an algorithm suitable for the EC-IoT based smart grids framework to predict the consumption data of the user. On one hand, this enables power supplier to timely understand the needs of the consumer and reasonably adjust relationship between supply and demand. On the other hand, the forecast information of acceptable price will be given to help consumers choose the electricity consumption period efficiently. Therefore, the dynamic pricing prediction plays an important role in smart grids. Generally, for forecasting the electricity prices there are many different approaches like Auto Regressive Integrated Moving Average (ARIMA) models, simpler Auto Regressive (AR) models modern techniques such as ANN, Fuzzy logic [36]. In this paper, considering the current demands in smart grids, we propose a real-time data prediction algorithm based on long short term memory (LSTM), which could deal with long term information dependency. LSTM is a special case of Recurrent Neural Network (RNN) [37]. However, unlike traditional RNN, LSTM will selectively remember or delete a piece of information based on whether it is useful or not. The LSTM is used in this study to forecast the price because this method has high capability to learn the complicated relationship between the input and output through a supervised training process with historical data. LSTM adds 3 gates, forget gates, input gates, and output gates respectively on the ground of RNN to avoid long-term dependency problem [24].

Mathematical Model:

Dataset:

$$\{x_1, x_2, \cdots, x_t\} \rightarrow y_t$$

where x_k means the input of time k, and the length of time series is t. Correspondingly, y_t is the surveillance information at time t.

Forget gate layer:

$$f_t = \sigma(U_f \cdot h_{t-1} + W_f \cdot x_t] + b_f) \tag{8}$$

Input gate layer:

$$i_t = \sigma(U_i \cdot h_{t-1} + W_i \cdot x_t] + b_i) \tag{9}$$

$$C_t = \tanh(U_c \cdot h_{t-1} + W_c \cdot x_t + b_c) \tag{10}$$

$$\hat{C}_t = f_t * C_{t-1} + i_t * C_t \tag{11}$$

Output gate layer:

$$o_t = \sigma(U_o \cdot h_{t-1} + W_o \cdot x_t + b_o) \tag{12}$$

$$h_t = o_t * \tanh(\hat{C}_t) \tag{13}$$

$$y_t = soft\max(h_t) \tag{14}$$

Computing of cross-entropy loss:

$$\min_{\theta} J(\theta) = \sum_{j=1}^{m} loss(\hat{y}_t, y_t)$$

$$\theta = [U_f, W_f, U_c, W_c, U_o, W_o, b_f, b_i, b_c, b_o] \tag{15}$$

where σ sigmoid function is an activation function that converts the output value to a value of $0 - 1$, thus retaining parts of information. x_t inputs vector to the LSTM unit, h_t outputs vector of the LSTM unit. W, U, b weight matrices and bias vector parameters which need to be learned during training. *Tanh* is an activation function that converts the output value ranging from -1 to 1.

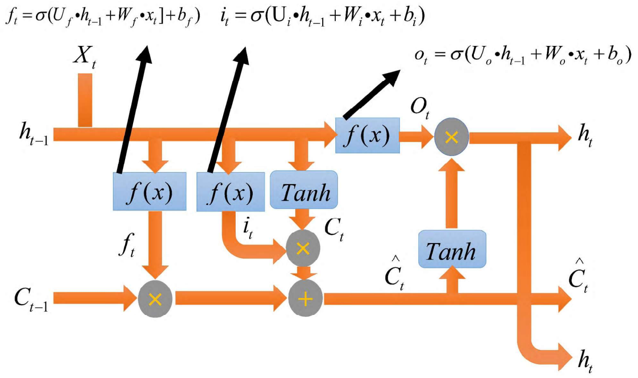
$f_t = \sigma(U_f \bullet h_{t-1} + W_f \bullet x_t] + b_f)$
$i_t = \sigma(U_i \bullet h_{t-1} + W_i \bullet x_t + b_i)$
$o_t = \sigma(U_o \bullet h_{t-1} + W_o \bullet x_t + b_o)$
X_t
O_t
h_{t-1}
$f(x)$
h_t
$f(x)$
$f(x)$
$Tanh$
f_t
i_t
C_t
$Tanh$
$\hat{C}_t$
$\hat{C}_t$
C_{t-1}
h_t

FIGURE 9. The LSTM unit.

The LSTM has three main phases to controll three gates as shown in Fig. 9. First, for the previous node h_{t-1}, x_t, selective forgetting content is generated through function 8 calculating f_t, in which 0 stands for completely discard, and 1 complete reservation. Next, $\hat{C}_t = f_t * C_{t-1} + i_t * C_t$ is to update the cell from C_t to $\hat{C}_t$. Finally, our final output is confirmed by the function. Algorithm 3 can predict the electricity price of the next moment in the light of the power consumption information in time series, and provide users with the power consumption information for the next period, hence reducing the power supply pressure, and also encouraging off-peak power use.

C. PREPROCESSING STRATEGY OF HIERARCHICAL DECISION-MAKING BASED ON TASK GRADING (HDTG) IN EC-IoT BASED SMART GRIDS

There are a large number of intelligent terminals in the power systems, and their demand responses are different. For example, some terminals need to respond to application service in real time, and some coordinate with cloud computing to analyse massive information to achieve global situational awareness. Besides, some devices need timely interactive communications to provide real-time edge computing intelligent services. In these services, it is an open problem how to evaluate the service level and offer a reasonable service processing strategy and network structure. To solve this problem, we propose an algorithm of preprocessing strategy of hierarchical decision-making based on task grading. First, the user initiates a service request, and then edge computing devices evaluates results according to the service demands, such as assessments for real-time demand service responses, task computational complexity, security levels, storage spaces, application demands, and data volumes.

Subsequently, the edge computing devices, in accordance with the task grading made by the access device, selects the corresponding policy method, which is mainly categorized

Algorithm 3 LSTM for Dynamic Pricing Prediction in EC-IoT Based Smart Grids

```
Input: the data-set $X$ and learning rate $l_r$.
Output: the prediction model $F(x)$.
Data processing.
Normalization of data $X = \frac{X-mean(X)}{var(X)}$.
Establish the training dataset $X_{train}$.
Establish the test dataset $X_{test}$.
Defining neural network variables and establishing the original LSTM model.
Calculate the Forget gate, using formula (8).
Calculate the Input gate, using formula (9,10,11).
Calculate the Output gate, using formula (12,13,14).
Initialize variables $U$, $W$, $b$.
Model creation was completed.
Using the training set to train the model.
Calculating the loss function according to cross entropy.
$\min_{\theta} J(\theta) = \sum_{j=1}^{m} loss(\hat{y_t}, y_t)$.
Using Adaptive moment estimation to optimize algorithm.
Getting the optimal solution when learning rate is $l_r$.
Updating parameter $U$, $W$, $b$.
Setting prediction model $F(x)$.
Output prediction model $F(x)$.
```

into four levels, (1) real-time processing in devices close to the user, (2) partial storage in the side of edge, (3) uploading for processing, and (4) deletion.

The rating is expressed as

$$level[N] = \sum_{i=1}^{4} \sum_{j=1}^{n} \frac{1}{2n} |sgn[T_i - f_j(x)] - 1| \qquad (16)$$

where T_i represents every evaluation basis, $f_j(x)$ is every evaluation function. Evaluation levels and results are shown below.

Results	0 or 1	2	3	4
Operation	Delete	Processing	Partial storage	Uploading
Devices Level	1	2	3	4

Algorithm 4 establishes a pre-processing level evaluation method suitable for the EC-IoT based smart grids.

V. NUMERICAL SIMULATIONS

In order to verify the feasibility of the above theory, we performed numerical simulations on data prediction, privacy protection, and transmission consumption with edge computing and cloud computing framework.

A. DATA PREDICTION

We use hypothetical data sets to simulate electricity prices in a urban area. In order to validate the effect of numerical simulation, we make the data set have a fluctuating trend with time. We have adopted algorithm 3, and respectively set the number of hidden layers as 10, the learning rate 0.0006, the training data set 3800, the test data set 2000, and the optimal solution iteration times 30 times in the simulation. The simulation results are shown in Fig. 10. It can be seen that this algorithm can accurately make predictions. As time passes, the results of prediction curve is more and more matched with the real values. The accuracy of the algorithm has been demonstrated.

Algorithm 4 Pre-Processing Level Evaluation Mechanism

```
Input: a message $x$, an adaptively chosen testing function $f_j(x)$, and $T_i$ is threshold for every evaluation level.
Output: the level of access devices Level[N].
$GM(X, f_j, T_1, T_2, T_3, T_4, Level[N])$.
The sensor sends task demand information to the edge computing nodes.
The setting of $T_i$ determines the standard of the scores of each test item, and can appropriately adjust the respective scoring benchmarks considering the importance of each test item.
For i=1 to 4.
    For j=1 to n.
        If $f_j(x) > T_i$, the edge computing node gives the evaluation result according to the item of the test. Among them, $T_i$ is evaluation criterion of the item.
        This item scores 1.
        Else.
        This item scores 0.
        End if.
    End for.
End for.
Output the sum of the individual evaluation items is counted. If the sum is 0 or 1, the level is 1. If the sum is 2, the level is 2. If the sum is 3, the level is 3. If the sum is 4, and the level is 4.
```

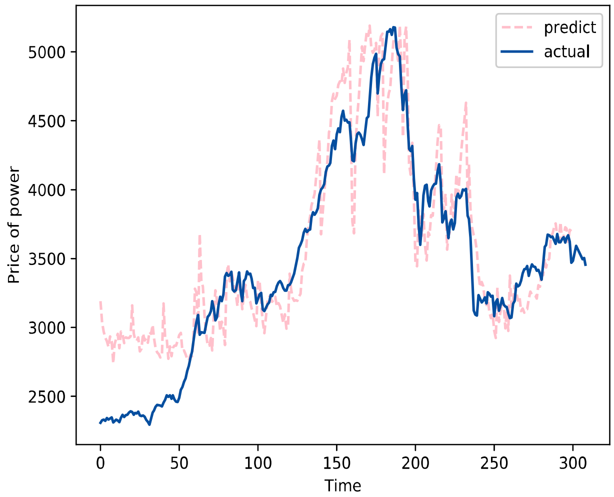

FIGURE 10. Data prediction.

The simulation results have shown that the LSTM algorithm can be used to predict the power price at the edge computing devices. Meanwhile, the consumer can

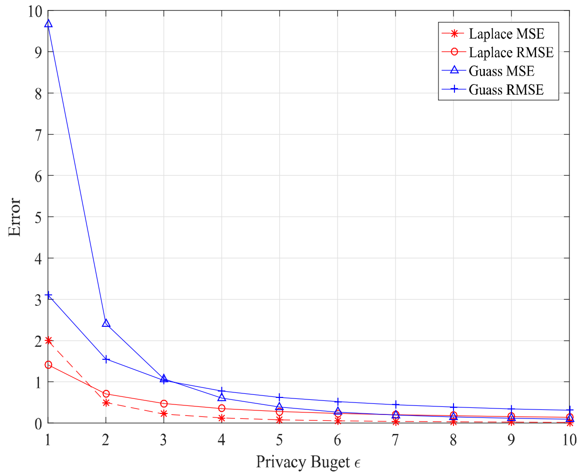

FIGURE 11. **Differential privacy.**

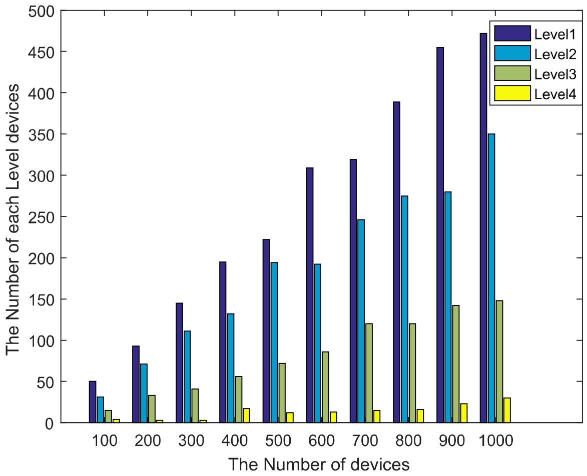

FIGURE 12. **The preprocess by edge computing.**

adjust the electricity consumption behavior in a reasonable way in accordance with predicted electricity price by edge computing devices. For example, when electricity price is high during the peak hours, the consumer can choose to avoid power consumption in the peak period as much as possible.

B. DATA PRIVACY PROTECTION

We have performed numerical simulations of two privacy protection mechanisms and compared the two mechanisms. We have used Matlab to randomly generate a private data set that needs to be protected. Then we have built the attack model according to Fig. 3. For the convenience of numerical simulations, it is assumed that the value of l_1 sensitivity and l_2 sensitivity of the attackers query function all are equal 1. The artificial noises are added to the query results of the attacker by algorithm 1 and 2, which is Laplace noise and Gaussian noise respectively. The mean squared error (MSE) and root mean squared error (RMSE) are taken as the availability evaluation, and ε the privacy budget. Then, the data set and the original data after the noise addition have been compared and analyzed. The smaller the privacy ε, the higher the privacy of the data, but lower the availability of the data.

The simulation results are shown in the Fig. 11. First, the two curves, with the increase of ε, the MSE and RMSE value all show a downward trend, indicating that the availability of the data is gradually improved when the privacy budget is reduced. Second, with the changes of ε from 1 to 10, we have found that the noise curve based on Laplace is under the Gaussian mechanism curve in general, showing that the overall performance of the noise of the Laplace mechanism is better than that of the Gaussian mechanism. Based on the performance results, we prefer to using the Laplace mechanism for privacy protection, while the Gaussian mechanism can be used as an alternative.

C. PREPROCESSING OF HIERARCHICAL DECISION-MAKING BASED ON TASK GRADING(HDTG)

It is assumed that 100 to 1000 power terminal devices are connected to the EC-IoT based smart grids, and task level evaluation is performed at the edge computing devices. The evaluation level is classified into four levels, and the number of devices at each level is counted. The simulation involves 2 steps. At first, we use Matlab to randomly generate the amount of 100-1000 device vectors. The vector owns 4 dimensions. The dimension value is evaluation score from 1 to 100 that are randomly generated. Then the algorithm 4 is applied to establish edge computing-based task scoring and grading strategy. Finally, setting T_1, T_2, T_3, T_4, and the value of each them is 60. As shown in Fig. 12, the simulation results have manifested that, in the case of different access devices, the edge computing devices grade the decision results for the services demand of 100-1000 devices by algorithm 4. Next, according to the task grading of access terminals made by edge computing devices with the purpose of ranking the task level, we have obtained the result from first level to the fourth level.

The demand response task of the access terminal is preprocessed by the edge computing devices. As a result, they perform corresponding processing on different task levels. For example, the edge computing devices locally process the low-level service requirements, but the tasks with higher-level response requirements which edge computing is incapable of processing should be uploaded to the cloud and processed in conjunction with cloud computing. This is how to reduce the amount of transmission data to be uploaded to the cloud. In the second simulation, it is assumed that the four bandwidths for uploading service demand responses is 5, 10, 15, $20 * 10^4$ bits per second and their transmission distance is different. Among them, the transmission distance of service demand responses that the grid architecture with cloud center require is much longer than that of the architecture edge computing deployed. The results of the hierarchical response of a large number of accessed devices are given by the last numerical simulation.

The simulation results are shown in Fig. 13 and Fig. 14, which mainly include four points:

1) The transmission bandwidth required by the traditional cloud-based grid is rising with the increase of the

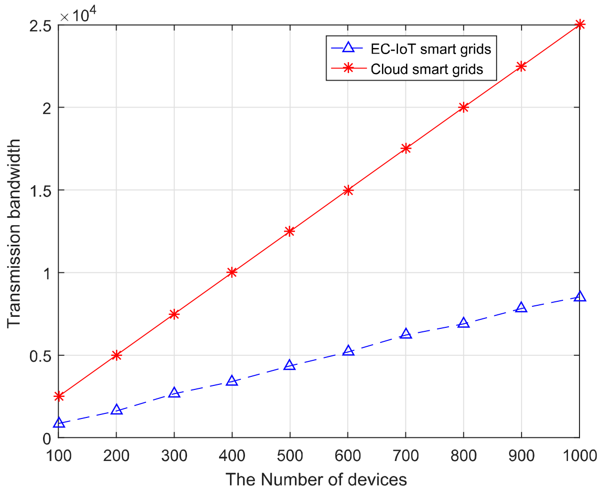

FIGURE 13. **The need of bandwidth.**

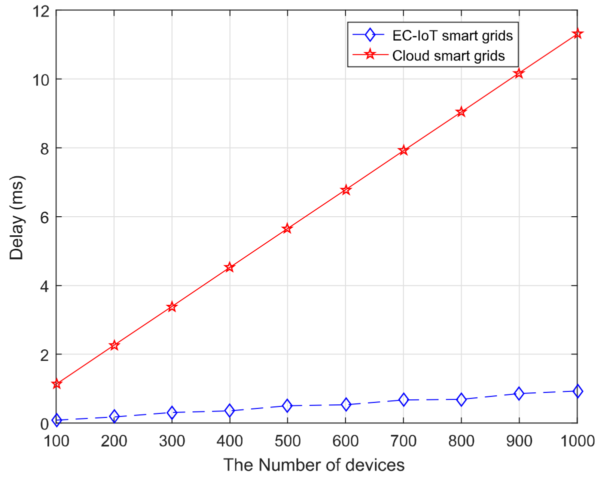

FIGURE 14. **The time delay.**

number of devices compared with EC-IoT based smart grids.

2) The requirement for transmission bandwidth of framework with edge computing is always smaller than that of cloud.
3) It is demonstrated that a power system with an edge computing architecture has the advantage of reducing transmission bandwidth.
4) Delay and bandwidth are two indicators of quality of service (QoS). From numerical simulation of bandwidth and delay, it can be seen that the QoS performance of the edge computing architecture is better than the cloud-centric smart grids.

VI. CONCLUSION

In this paper, we have mainly focused on solving the problems caused by the IoT-based smart grids, such as the rapid response for user's requirement, intelligent scheduling, intelligent maintenances, intelligent response for consumers, and rapid market responses. Here, we have proposed an architecture introducing edge computing into IoT-based smart grids. Moreover, in the three major scenarios of power systems that power distribution, Micro-grid, advanced metering systems, application of edge computing are well represented. Whether it is real-time response or edge computing-based service, both of them fully reflect its advantages in comparison with traditional cloud-based power systems. Subsequently, we have proposed algorithm strategies, data privacy protection, data prediction, and task grading strategies appropriate to the new architecture. From numerical results, we have concluded that our proposed strategy can effectively protect the data privacy in the system and bring new opportunities for the realization of IoT-based smart grids. In future work, we will implement edge computing into power grids to support applications in reality. In addition, the business value of edge computing applied in power systems will be manifested and practical feasibility of our algorithm will be verified as well.

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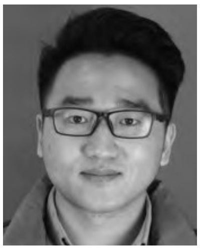

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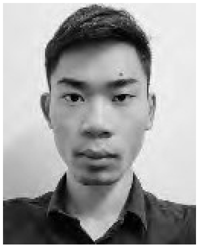

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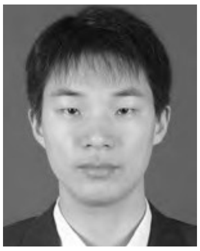

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